# CASE HISTORIES

# OF

# WETLAND RESTORATION

U.S. Department
of Transportation

**Federal Highway
Administration**

## NOTICE

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# List of Exhibits and Tables

## List of Acronyms

| | |
|---|---|
| ADID | Advanced Identification |
| CDFG | California Department of Fish and Game |
| CALTRANS | California Department of Transportation |
| CDNR | Colorado Department of Natural Resources |
| CDOT | Colorado Department of Transportation |
| CCRs | Conditions, covenants, and restrictions |
| CEQ | Council on Environmental Quality |
| cfs | Cubic feet per second |
| COE | U.S. Army Corps of Engineers |
| DER | Department of Environmental Regulation (now called the Department of Environmental Protection) |
| DNR | Department of Natural Resources |
| EIR/EIS | Environmental Impact Report / Environmental Impact Statement |
| EPA | U.S. Environmental Protection Agency |
| FAIR | Federal Agricultural Implementation and Reform Act |
| FHWA | Federal Highway Administration |
| FWPCA | Federal Water Pollution Control Act |
| fmsl | Feet above mean sea level |
| FWS | Fish and Wildlife Service |
| FDA | Florida Department of Agriculture and Consumer Services |
| FDOT | Florida Department of Transportation |
| HEP | Habitat Evaluation Procedure |
| HSI | Habitat Suitability Index |
| HUs | Habitat Units |
| HGM | Hydrogeomorphic classification system |
| KARA | Keys Artificial Reef Association |
| MOA | Memorandum of Agreement |
| NEPA | National Environmental Policy Act of 1969 |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NRCS | Natural Resources Conservation Service (formerly Soil Conservation Service) |
| NRI | Natural Resources Inventory |
| OSDS | On-site disposal systems |
| SMS | Salvaged marsh surface |
| SCS | Soil Conservation Service (now called the Natural Resources Conservation Service) |
| SAMPs | Special Area Management Plans |
| USDA | United States Department of Agriculture |
| VELB | Valley elderberry longhorn beetle |
| WRDA | Water Resources Development Act |
| WRP | Wetland Reserve Program |
| WET | Wetlands Evaluation Technique |
| WDNR | Wisconsin Department of Natural Resources |
| WDOT | Wisconsin Department of Transportation |

# CHAPTER 1

## INTRODUCTION

Blue sky, green grass, rich soil, fresh air, clear water, natural habitat, open space, animals, life. Colorful images of our world, our planet, our home. The history of life on earth has been one of interaction between living things and their surroundings. To a large extent, the earth's vegetation and its animal life have been molded by the environment. The opposite effect, in which life modifies its surroundings, has been slight during the whole span of earthly time. Only during this century have humans acquired significant power to alter the nature of the world.

We are linked to all living things. Jolted from our attitudes and patterns of domination and the destruction of nature in recent decades by such landmarks as *Silent Spring*, by Rachel Carson, we have come to realize we cannot continue as a throw-away or cut-and-burn society without frightening consequences to all life on earth. Hopefully, we have come to understand our world better. We cannot poison it, kill it, replace it, or even ignore it, without some effect. This principle applies to all the fundamental elements of our planet–air, water, and soil. Our understanding and our stewardship warrant that we see our world with new eyes--to go back to nature, repair what has been damaged, restore what we can, and save pristine areas. We cannot ignore our vital role as stewards of the earth.

One of our most important resources is water--sustainer of life in oceans, seas, rivers, lakes, ponds, and streams, or in marshes, swamps, bogs, and water holes, also known as wetlands. The latter provide fresh water to animals and fish and maintain a delicate ecosystem. They reduce flooding by absorbing excess rainwater, filter pollutants, afford habitat to water fowl, and offer beauty, recreation, and space. They are vital and they are valuable. But they have been drained, polluted, filled, or destroyed in some manner.

Scientists estimate that colonial America had at least 895,000 hectares (ha) (220 million acres) of wetlands. Since the 1780's, nearly half of the United States has lost at least 50 percent of its wetlands. Although the rate of loss has been dramatically reduced in recent years, the United States continues to sustain a net loss of approximately 40,470 ha (100,000 acres) of wetlands each year--from agricultural conversion, erosion, urban development, and highway construction. What can be done to stop this trend or reverse it?

The President, in recognizing the important value of wetlands to the Nation, announced a comprehensive 40-point Wetlands Plan in 1993 to make Federal wetlands programs more fair, more flexible, and more effective. The interim goal was no overall net loss of the Nation's remaining wetlands, and the long-term goal of increasing the quality and quantity of the Nation's wetland resource base. The 1998 Clean Water Action Plan will help reverse the historic pattern of wetland losses and achieve a net increase of 40,470 ha (100,000 acres) of wetlands each year, beginning in 2005. The Federal Highway Administration's 1998 National Strategic Plan has included the goal of increasing net wetland area (hectares/acres) resulting from Federal-aid highway projects by 50 percent in 10 years.

In view of these goals, restoration of wetlands has become imperative. The how and why is the focus of this report. Restoration is defined as "the process of establishing the original site characteristics (ecosystem) that existed prior to land disturbance." (Gerling)

Although wetland restoration as a science is still young and the success or failure of this process is still too difficult to measure, several areas in four States–California, Colorado, Florida, and Wisconsin–have been restored with viable results. The four projects, covering a 30-year period beginning in the 1960's, help provide useful information on factors that led to successful restoration. Three of these were associated with highway projects in the 1960's, and all four were completed in the 1980's.

A careful look at those older projects, which have been considered "successful" by participants, can provide a wealth of knowledge about whether "restored" wetlands can truly compensate for the losses of once-natural wetland resources. Such observation constitutes most of this report.

The four geographically diverse projects are: (Exhibit 1-1):

- **CALIFORNIA:** The mitigation of riparian and wildlife habitat losses anticipated in the construction of a 113- ha (280-acre) commercial development in Yolo County on the Sacramento River in California. The development was designed to bring much needed jobs, economic development, and tax revenues to the fast growing region. It involved the replacement of riparian habitat along the river, wetlands, and the habitat of the endangered elderberry valley beetle (Tesmocerus californicus dimorphus).

- **COLORADO:** The mitigation of wetland and riparian impacts caused by the widening and straightening of a stretch of mountain highway west of Denver, Colorado, to improve the safety of a road heavily used by traffic headed for the nation's major ski resorts. The improvements required moving the North Fork of the South Platte River and the loss of sub-alpine riparian wetlands.

- **FLORIDA:** The mitigation of wetland loss incurred by the replacement of 37 old and unsafe bridges on the Florida Keys Overseas Highway that stretches from the tip of the Florida peninsula to the southwestern-most island of Key West. Major impacts anticipated from the action were the destruction of sea grass and mangrove communities, increased potential for shoreline erosion, and interference with hydrologic exchanges between the Florida Gulf to the north of the Keys and the Atlantic Ocean to the south.

- **WISCONSIN:** The mitigation of wetland losses incurred by the construction of a six-lane limited access roadway, the South Madison Beltline, to skirt the capitol city of Wisconsin, to alleviate severe traffic congestion and improve safety. The selected route for the new highway transected the Yahara River Marsh and, by destroying a portion of the marsh, would affect some of the area's most valuable wildlife habitat.

*Why were these four cases considered successful?* In each one, the environmental review and negotiation process set in motion by the National Environmental Policy Act of 1969 (NEPA) and Section 404 of the Clean Water Act prevented wetland losses. Although quantitative assessments were relied upon far more than qualitative assessments, for both the affected and the newly created wetlands, a potential net gain of wetland functions characterized all four cases.

Dahl (1990) and others have made an attempt to quantify the number of remaining wetlands on a national scale; however, this information is not always available on a local scale, where it would be useful in mitigating wetland losses. Knowing where and what type of wetland to create would greatly facilitate the overall ecological success of this Nation's restoration activities. The necessary planning activities, such as are being pioneered in the State of Washington, must be improved and expanded. In the absence of this planning structure, individual restoration projects would benefit from an understanding of the landscape position and structure of the intended prototype.

The relative youth of wetland restoration science prevents definitive answers to the questions of whether the functions gained were equivalent to those that were lost, or even whether they should have been. Considering the rapid growth of our scientific understanding of natural wetland processes and restoration techniques, along with the body of knowledge being developed in our public and private institutions, many of the answers to wetland restoration questions will most likely be available in the next decade. In the meantime, the answers derived from the four case histories indicate great promise for the future of wetland restoration in the United States.

As we look at the four case histories, we need to ask the following questions to determine **what makes wetlands restoration successful**:

1. How do we **define a successful wetland restoration**?

2. What **planning and administrative elements have to be present** in the restoration planning process for a successful result?

3. What **conditions contribute to those elements**?

4. What **technical, geological, and biotic conditions and criteria are most important** in implementing a successful restoration?


EXHIBIT 1-1: PROJECT DISTRIBUTION

# CHAPTER 2

## WETLANDS IN THE NATURAL LANDSCAPE

### INTRODUCTION

Since the last ice age (10,000 to 25,000 years ago), wetlands have, to one degree or another, existed in every state, from Maine to Florida to Alaska and Hawaii. Wetlands are even found in the more arid west, including Utah, Nevada, New Mexico, and Arizona, as well as in the frigid climes of Alaska. However, wetlands are more abundant in regions where precipitation exceeds evapotranspiration and where the topography is reasonably flat with soils underlain by impermeable materials such as clay or limestone. Because wetlands readily form where groundwater is high or it discharges to the surface, as with peatlands and fens, they can be found on hillsides, in glacial valleys, on flood plains and fluvial fans, and along shorelines, where such conditions exist.

### WHAT ARE WETLANDS?

Wetlands are areas that are transitional between terrestrial and aquatic habitats. Examples of wetlands include prairie potholes, freshwater marshes, swamps, fens, bogs, wet meadows, and fringe areas of lakes and estuaries that have emergent vegetation. The U.S. Army Corps of Engineers defines wetlands for the Section 404 Regulatory Program as those areas which are inundated or saturated with ground or surface water at a duration and frequency sufficient to cause the development of hydric soils and a prevalence of hydrophytic vegetation.

### HOW ARE WETLANDS FORMED?

The formation of a wetland is a relatively simple process. It involves the presence of water above, at, or near the soil surface for periods of time long enough to cause anoxic (oxygen lacking) conditions at and below the soil surface. Given modest variations in climate, soil type, water source, and duration of saturation or flooding, a wide variety of wetland types can form. For example, bogs develop in relatively cool, moist climates on sites with a confined drainage system, deep depressions, and continuous saturation. In comparison, sedge meadows occur in cool, relatively dry climates, require less water, and are intermittently saturated or flooded.

A number of factors operate in and on the landscape to form the appropriate hydrologic conditions for wetlands. These factors affect the movement and distribution of water in space and time. They are both geomorphic and biotic. The fidelity with which these factors are copied determines the path of restoration and the degree of success.

Along our coastal zones (excluding the coastline of the Great Lakes), topography and tidal cycles define the relationship between soil and water. Further inland, wetland conditions are defined by the interaction of landforms with freshwater and tidal influences. The principal driving function of interior, freshwater wetlands is hydrology--the cycle of water on the site. Whether palustrine, lacustrine, or riverine, freshwater wetlands are driven by the rainfall-runoff-groundwater relationships in their geographic region. In the pothole region, which spans the glaciated Midwest from Iowa to Alberta, Canada (Van der Valk, 1989), the small surface depressions in the complex topography and the ambient hydrology provide the conditions for palustrine wetlands to form. The presence of a lake establishes the necessary conditions for lacustrine wetlands, but the level of the water surface relative to the shoreline determines the nature and extent of the wetland fringe surrounding it.

## FACTORS THAT DETERMINE WETLANDS

The factors determining wetland characteristics and boundaries are defined by the Federal Clean Water Act (Section 404) as well as the physical environment. The Section 404 regulatory definition of wetlands involves three interdependent components: hydrology, soils, and plants. The particular soils and plants, in large part, result from the in situ geology and ambient hydrology.

### Landforms

Where landforms impound or control water to a sufficient extent, wetlands form as a result. The depressions left behind by the retreating ice sheet of the Wisconsin glacier serve as ideal receptacles for retaining water and nurturing the formation of hydric soils and the propagation of hydrophytes (water-loving plants). The natural levees bordering the Sacramento River in California trapped floodwaters in the overflow areas. These waters defined and supplied vast marshes with their critical nutrients. Glacial moraines, eskers, potholes, and lakes, along with fluvial features, such as swales, streams, rivers, bars, natural levees, and fans, as well as marine landscapes, for example, intertidal mud flats, tidal pools, aquatic beds, and coral reefs, all form the infrastructure of North American wetlands. The inhabiting plants and animals then modify these structures.

### Plants

From a purely structural point of view, the important characteristics of the plant community in the formation and persistence of wetlands are the root structure, stem density, and plant mass. The effects of these factors extend to both living and dead plant materials. Living plants in streams, lakes, and estuaries slow the movement of water, causing an increase in water depths and area of inundation. Plant detritus has a similar effect. It displaces water and increases boundary friction. Plants affect the hydrologic cycle, depending on the community type (e.g., grasses versus trees). Interception, storage, and transpiration are affected by the physiological activities of plants. In the soil profile, organic material retains water in the vadic (unsaturated) zone, critical to the propagation and survival of all vegetation, including hydrophytes. Plants and plant detritus provide the expansive stable surfaces and niches supporting the macro- and microorganisms responsible for decomposing and recycling nutrients and other chemical constituents in the water and providing habitats at the base of the food web. Thus, through their control of water depth, and thereby anoxic conditions, and their contribution of organic matter, plants are important factors in the formation of hydric soils.

## Peat

The significance of the "plant factor" should not be underestimated. One illustration of the importance of plants is the deposition of peat in bogs and fens. Bogs are one of the most widely distributed types of wetlands, with over 100 million hectares (ha) (247 million acres) occurring in Canada alone. Peat consists of the organic remains of plants which accumulate most readily under the cool, moist conditions predominant in northern temperate climates, although they have been found as far south in the United States as Illinois, Indiana, and West Virginia. Its formation requires conditions of low oxygen concentration and an excess of rainfall over evaporation/transpiration. Peat has been mined as fuel worldwide for thousands of years. Peat accumulation results in lowering of the pH as the water flows through or resides in the peat. Examples of peat accumulating plant communities are bogs, fens, and muskeg. Bogs often form over old lake beds or in north temperate forests over wetlands which have filled in over time. Fens are wetlands which occur in conjunction with springs having high concentrations of dissolved limestone. Muskeg is the dwarf spruce/fir bog community which occurs in high northern latitudes.

In an essay on the origin and distribution of peat in Michigan, by Charles Davis (1907), several interesting observations were cited, including one by the French geographer previously cited, E. Desor (1879):

> ...in Michigan, rivers of considerable size which are barred by dams, making thus a quantity of lakes and ponds which would not exist without them. It is evident from this that, without these dams, the lake, and peat deposits, which are found at the bottom of these ponds, would be less numerous. The beavers have thus exercised an influence not only on the distribution of waters, and the consequent fertility of the soil but also up to a certain point even upon the distribution of recent rock formations.

## Natural Dams

### 1. Benefits

There are numerous historical references to the intensive and extensive drainage controls due to fallen trees and other plant debris. In 1850, the French geographer E. Desor (1879) explored the Upper Peninsula of Michigan. He encountered numerous debris dams as he traveled up the Monistique River. He reported that:

Such barriers are not rare in the forest, particularly if the inclination of the river is small. A trunk being carried by the river suddenly can be caught in the middle of a meander. If the stream is not strong enough to move it, it stays there and a second trunk comes to attach itself to the first one and many others come along and finally their branches get intertwined and they finally form a dam which can get bigger and bigger ad infinitum.

Some of the barriers are rather big and seem to be rather old because you can find trees growing on top of the floating trunks.

He reported broad swampy areas all along the course of the river, undoubtedly due to the hydraulic controls of the debris dams. The structures viewed by Desor are dwarfed by one on the Red River in Oklahoma (Foreman, 1937):

> The phenomenon known as the Great Raft was a succession of log masses that choked the Red River for a distance of more than a hundred miles and was of unknown antiquity. It had existed so long as to assume permanent form and it was said that forest trees were to be seen growing upon it; horsemen could ride over it not knowing that they were passing over the water of the river. When removal of the Choctaw Indians was commenced in 1832, orders were given to attempt the removal of the raft so that navigation of the Red River could be established and supplies for the emigrating Indians could be brought up the stream.... Destruction of the raft was carried on under the command of Capt. Henry M. Shrive with a force of 150 men and four snag-boats. It was five years before Shrive could report the completion of the work.

Less massive debris obstructions were common throughout North American drainage ways, from the Connecticut to the Sacramento Rivers. Geographic names often reflected their presence, e.g., Embarras (the French word for obstruction) Portage in Alberta, Canada, and the Embarras River in Illinois. George Washington, in the 1780s, was a proponent of removing sandbars and snags on the Ohio River to improve navigation (Frost and Misch, 1989). And the ever-popular writer Samuel Clemens often lamented, in story and in life, the hazards of navigating the Mississippi and Ohio Rivers. He chronicled the dangers and the details of the numerous obstructions on the rivers. He even named one of his storied characters, Tom Sawyer, after the American term, sawyer, meaning a tree swept into the river with one end stuck in the mud and the other bobbing up and down in the current. The various States and the Federal government worked to remove some obstructions in the late 1700s and early 1800s. But in 1827, the first Rivers and Harbors Act empowered the Federal Government to move in earnest. By the 1870s, few obstructions remained. As a result, hydraulic profiles were lowered and wetland areas reduced.

### 2. Consequences of Dam Removal

The consequences of removing such natural dams are both physical and biological. Wetlands upstream of such dams are drained, and sediment is flushed downstream. Habitats, for both plants and animals, are lost. These consequences are illustrated by the removal of a log jam on Locust Creek, a tributary of the Grand River, which is tributary to the Missouri River in north-central Missouri. A large volume of sediment had been impounded by the log jam and the backwater supported an abundance of wildlife. When the logs were cleared, the habitat was destroyed and the sediment was flushed downstream and deposited over the herbaceous layer of another forested wetland, altering both habitats. (Exhibit 2-1).

## Animals

A number of animals are important to the creation and survival of wetlands. Birds, for example, move seeds from one wetland to another. Muskrats shape and harvest the plant community. Bacteria and other benthic organisms shred and mineralize the detritus. But the organism most responsible for creating and preserving the prehistoric wetlands in North America is the beaver.

Beavers very purposefully retain water on the land surface for their own welfare and safety. Their dams, traversing swales, streams, and rivers, force water to spread across the adjacent and upstream landscapes and, by design, maintain shallow water depths, ranging from 2 meters (m) (6.6 feet) over the central portion of the impoundment to only 5 - 8 centimeters (cm) (2 - 3 inches) on the perimeter. These are ideal depths for a wide variety of wetland types--deep and shallow marshes, sedge meadows, and wet prairies. In a similar manner, beavers have controlled, and in some cases still control, the outlets or overflow structures of lakes and potholes, influencing the presence and extent of the associated lacustrine and palustrine wetlands. Beavers also construct channels by which to reach and convey building materials and food supplies safely (Mills, 1913). The channels, some 300 m (1,000 feet) or more in length, extend the hydrologic effects well beyond the limits of the impounded water.

The significance of beavers is not well established by scientific observation; however, some observations and population estimates shed a little light on the subject. In the 1930s, two geomorphologists, studying streams in the Adirondack Mountains, concluded that beavers were the geologic agent responsible for the creation of the region's drainage systems (Ruedemann and Schoonmaker, 1938). They theorized that the level flood plains, which were perpendicular to the stream channel but stepped longitudinally, were the artifacts of beaver dams. Beaver dams trapped eroded materials, and built, in sequence, marshes, meadows, and ultimately, drier flood plains. Although there is not a systematic body of knowledge validating this theory, scattered evidence supports the notion (Butler, 1995).

# TYPES OF WETLANDS

Wetlands are found on landscapes ranging from alpine slopes to ocean coastlines. This landscape range has been subdivided and each element categorized by Cowardin et al. (1979), as shown in Table 2-1.

Landscape position and structural form, along with hydrology, define the type of wetland. The first two systems, marine and estuarine, function more under the influence of geomorphology and hydrology (tides), but can be affected by plants and animals. The other three systems, riverine, lacustrine, and palustrine, are defined by geomorphic (geology and land form), hydrologic, and biotic factors. A wetland can shift from one system to the other depending on the presence or lack of hydraulic controls exerted by biotic factors. In fact, for the same reasons, they can shift from one landscape position to another.

A small beaver dam constructed across a narrow valley can result in shifting the wetland type from riverine to lacustrine, as can be observed in northern Minnesota. A lacustrine wetland can be altered by the failure of a controlling dam and turned back into a riverine wetland. Palustrine wetlands can change from open water systems to deep marshes, to sedge meadows, and finally, to mesic prairie through the process of erosion and deposition of soil material.

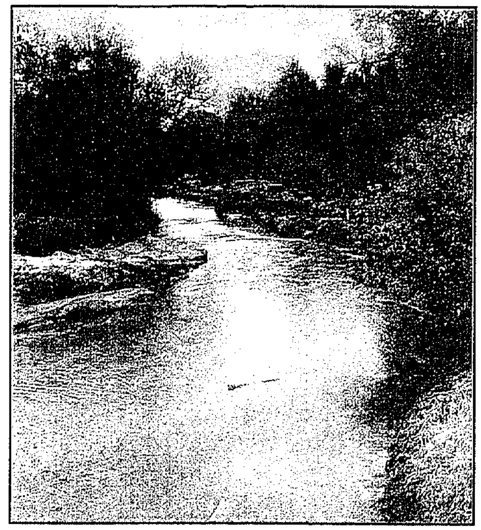
Regardless of the landscape position of the wetland, its habitat and value to humans relate to its physical structure and nature: water depth, surface area, wetted surface, and frequency of inundation or desiccation. These parameters define the plant community, which, in combination, form the habitat structure. The plant species making up the botanical component of the structure, in turn, depend on the quantity of water and frequency of inundation or saturation as well as the typical quality of the surface and groundwater. The hydrology, plants, and edaphic (soil) organisms form the supporting soils.

## Table 2-1: Cowardin's Categories

| System | Subsystem | Class | Subsystem | Class |
|---|---|---|---|---|
| Marine | Subtidal | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>reef | Intertidal | Aquatic bed<br>Reef<br>Rocky shore<br>Unconsolidated shore |
| Estuarine | Subtidal | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>reef | Intertidal | Aquatic bed<br>Reef<br>Streambed<br>Rocky shore<br>Unconsolidated shore<br>Emergent wetland<br>Scrub-Shrub wetland<br>Forested wetland |
| Riverine | Tidal | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>Rocky shore<br>Unconsolidated shore<br>Emergent wetland | Lower Perennial | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>Rocky shore<br>Unconsolidated shore<br>Emergent wetland |
| | Upper Perennial | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>Rocky shore<br>Unconsolidated shore | Intermittent | Streambed |
| Lacustrine | Limnetic | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed | Littoral | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>Rocky shore<br>Unconsolidated shore<br>Emergent wetland |
| Palustrine | | Rock bottom<br>Unconsolidated bottom<br>Aquatic bed<br>Unconsolidated shore<br>Moss-Lichen wetland<br>Emergent wetland<br>Scrub-Shrub wetland<br>Forested wetland | | |

*Source*: Cowardin, 1979.

Log jam impounding water and creating habitat



Channel section after removal of log jam

Sediment released by removal of log jam smothering herbaceous layer in forested wetland

EXHIBIT 2-1: THE EFFECTS OF LOG JAMS ON LOCUST CREEK IN NORTH CENTRAL MISSOURI (photographs by Ken McCarty, Missouri Department of Natural Resources)

Landscape position relative to need and supporting resources is an important consideration in creating or restoring a wetland, and the value of the wetland is inextricably tied to its position. The landscape position affects, to some degree, the human benefits derived from a wetland, such as flood control, wildlife habitat, or timber harvest. Wetlands serve best for flood control if they are located near an area of potential damage (Ogawa and Male, 1983). A wetland near an outfall of a storm sewer or wastewater treatment plant can provide greater water quality benefits for those structures than one at a distance downstream or upstream. The value of wetlands as wildlife habitat depends on the adjoining resources meeting its total needs. Where trees, or other structures for roosting are lacking, bats will tend not to forage in a wetland (French, 1998). Without safe access, primarily through stream channels or swales, mammals or fish are not likely to inhabit an otherwise suitable wetland either.

Species diversity undoubtedly was supported in a grand way by wetlands in a natural landscape. Today, however, plant diversity is too often taken as the sole criterion of successful restoration, relegating such critical functions as flood control, groundwater recharge, and water quality management to positions of secondary importance, if they are considered at all. These latter functions, if given greater consideration in restoration, can help sustain the aquatic ecosystem far beyond wetland boundaries.

The capacity of a wetland to store water and prevent it from moving too quickly through the watershed can provide for sustained base flow, water quality treatment, and biodiversity. For example, alpine wetlands can be used to hold back runoff during spring melt and reduce the erosive force of high flows as they cascade downstream. At the same time, these wetlands can provide homes for beaver and forage for elk. As they provide flood storage, water quality is benefitted as well. Generally, the longer the water is retained within a wetland the greater the opportunity for recycling nutrients and removing unwanted contaminants. During the long, dry summers, water can be released from subsurface storage to provide for the in-stream needs of fish, macro invertebrates, and other organisms.

## WETLAND FUNCTIONS

Wetlands play numerous roles in the landscape, and many authors have listed and characterized these roles (National Research Council, 1992). By far, the most fundamental is their hydrologic role.

Hydrology is the study of the movement of water from the atmosphere, across the land's surface, and back to the atmosphere. Throughout this cycle, numerous processes control the quantity of water that is either in motion or in storage and the pathways that the water follows (Exhibit 2-3). The processes include precipitation (rainfall and snow), interception and surface storage, infiltration, percolation, soil and groundwater storage, interflow, base flow, streamflow, evaporation, and transpiration. These processes apply to all elements of a watershed: forests and prairies, grassed and paved surfaces, and streams, lakes, and wetlands. They apply in every climatic region, desert or tropical landscape. The only differences among these varied landscapes are the quantities and principal paths of storage and movement over time.

Water quality must be appended to the definition of hydrology, for water quality and quantity are inextricably tied. The rate of flow affects the degree of chemical treatment and, ultimately, the quality of water moving from one reach or body of water to another. Wetlands, in particular, not only affect the rate of flow but the quantity of water, which affects the chemical quality. Wetlands generally slow the movement of water, allowing greater opportunity for evapotranspiration and groundwater recharge, thus reducing the amount of water and increasing the opportunity for bio- and geochemical reactions to take place.

The interaction of wetlands with surface, ground, or vadose waters establishes the conditions for all of the other functions, whether they are related to wildlife, water quality management, flood control, or the production of food and fiber. Further, wetlands help maintain the necessary hydrologic conditions for their own survival as well as for surrounding habitats. They act to store water during high flow periods, releasing it during droughts for their own use as well as for wetlands downstream. They prevent and reduce turbidity, facilitating the growth of submerged aquatic vegetation. These and many other hydrologic functions are affected by wetlands.

These reactions are further facilitated by the presence of more interactive surfaces (plant leaves, stems, and detritus), shallow depths, which promote aeration and settling, and the underlying anoxic zone, which promotes denitrification and immobilization of heavy metals, among other processes. These hydrologic and chemical interactions must be assessed together. As observed by Kusler and Kentula (1990), "Careful attention to wetland hydrology is needed in design...wetland hydrology is the key (although not necessarily sufficient in itself) to long-term functioning systems."

Wetlands are not efficient hydraulic structures; that is, they do not move water quickly through small channels. On the contrary, they are reasonably good at removing water from the surface flow path. Unlike a prismatic channel, such as might be designed by an engineer, the wetted surface of a wetland is at least an order of magnitude greater. This causes increased boundary friction, slowing the movement of water. Moreover, the surface area to depth ratio of a wetland is at least two orders of magnitude greater than that of a prismatic channel; consequently, a greater percentage of the water is exposed, and ultimately lost, to evaporation and infiltration. The end result is that wetlands reduce watershed yield. In a recent study of 8 watersheds in Wisconsin (Hey and Wickencamp, 1998), their yield ranged from 34.3 to 25.9 cm (13.5 to 10.2 inches) per year corresponding to an increase in wetlands from 2 percent to 20 percent of the land surface (Exhibit 2-4). This constitutes a 24 percent reduction in yield relative to an 18 percent increase in wetlands.

Wetlands affect other hydrologic characteristics as well. For example, low flows in the Wisconsin study were shown to increase with an increase in wetlands. In order to sustain the reduction in yield, in the face of an increase in base flow, high flows were decreased with an increase in wetlands. As the range of flow (the difference between high and low flow) is reduced by the presence of wetlands, so is the frequency of flow and stage fluctuations. Using, as the representative statistic, the number of excursions above the mean daily flow value equaled or exceeded 50 percent of the time, the excursion frequency ranged from 19 to 7 per year--the greater the percentage of wetlands, the fewer the excursions (Exhibit 2-5).

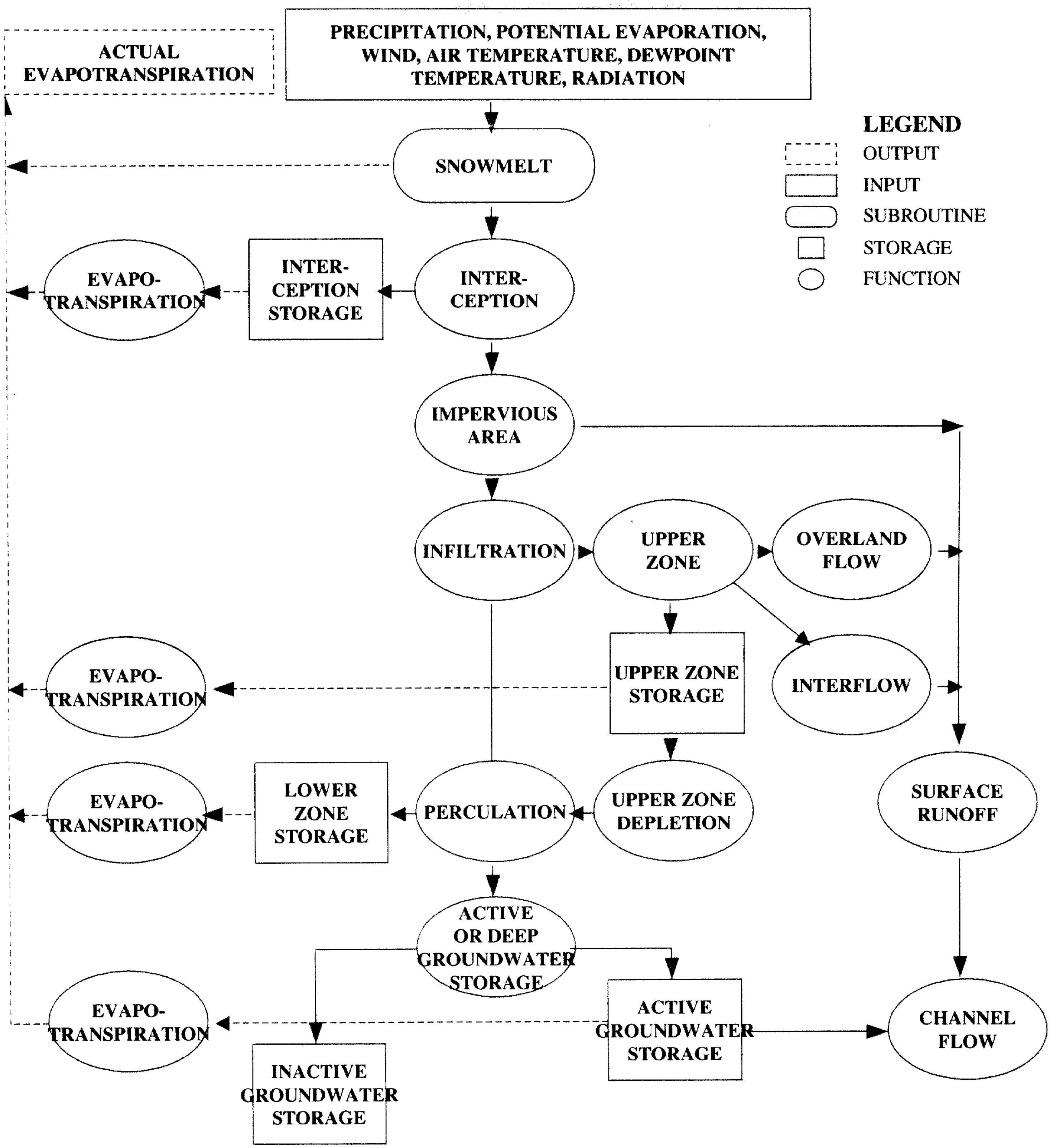



EXHIBIT 2-3: HYRDOLOGIC PROCESSES (ADAPTED FROM HYDROCOMP, 1967)

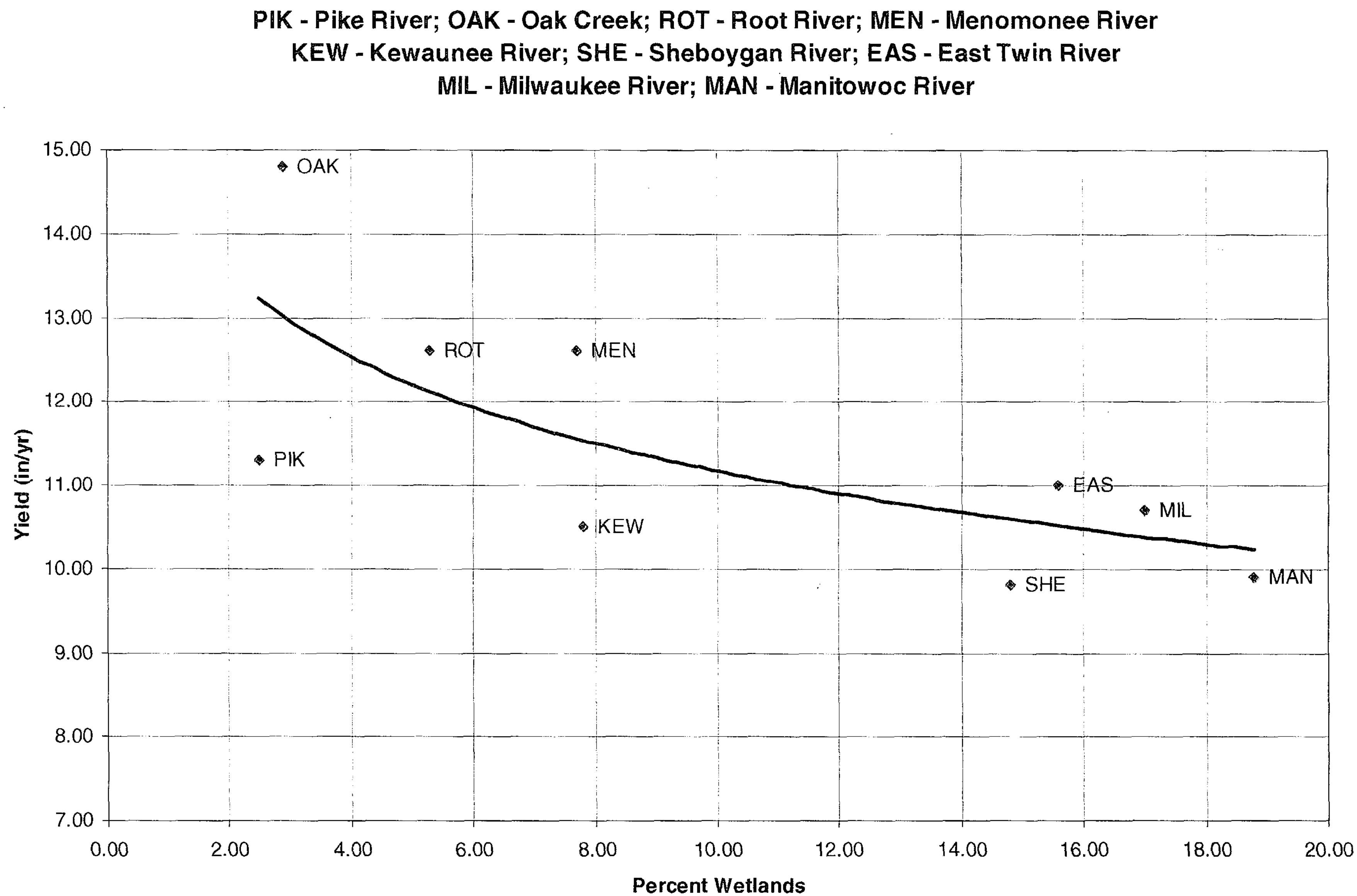



EXHIBIT 2-4: WATERSHED YIELD (Hey, in publication)

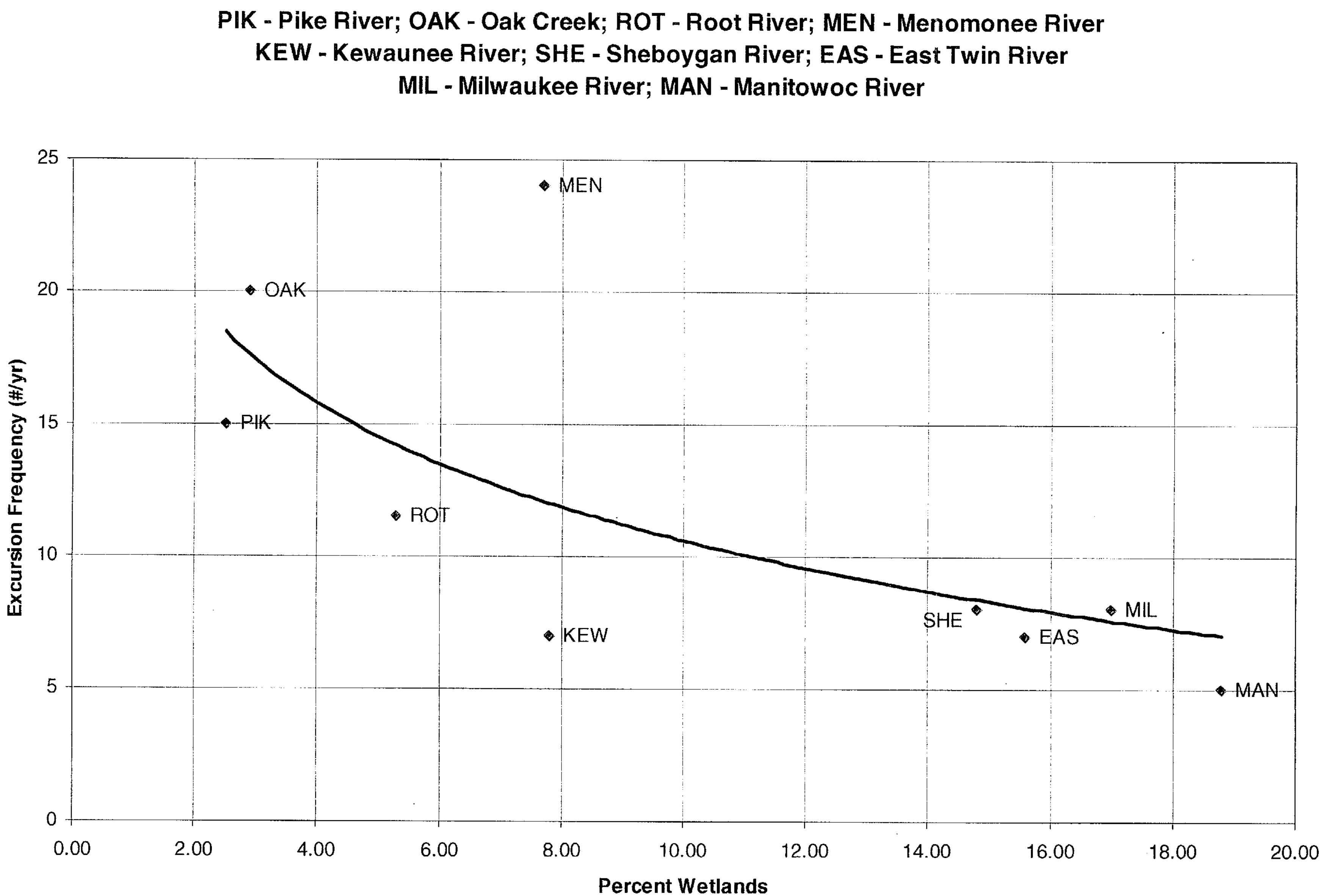



EXHIBIT 2-5: EXCURSION FREQUENCY (Hey, in publication)

The modulation of streamflow by wetlands can produce both positive and negative values. Although the reduction of yield may be viewed as bad, particularly from the surface-water supply perspective, the result is not all bad. Part of the loss is to groundwater, which can be accessed through wells. Higher groundwater levels and larger groundwater supplies are viewed, in many parts of the United States, as a benefit. Higher base flows provide better in-stream habitat and dilution of undesirable constituents. They also accommodate other human needs such as water supply and navigation. In fact, many smaller watersheds, which were perennial prior to agricultural and urban development, are now ephemeral because of the loss of wetlands. Before their modulating wetlands were drained, these streams supported water mills and other uses requiring year-round flow.

Native Americans understood the role of wetlands in sustaining streamflow, and they recognized the role that beavers played in creating impoundments and wetlands (Morgan, 1991). In the arid west, they were reluctant to kill the animal because, Morgan concludes, these early peoples well understood the environmental consequences--loss of critical water resources and wildlife habitat. Beaver dams and the impounded water attracted a wide range of fauna and flora that were a convenient source of food for the native populations. So important was the beaver that it was embodied in their religious beliefs, which underscored its importance and reinforced the prohibition against hunting the animal. These beliefs, in turn, preserved and sustained wetlands. Europeans immigrants, on the other hand, decimated the beaver population, cleared and drained these natural structures, and then built large, isolated reservoirs to protect against flooding and to store the increased high flows for release during low flow periods. These reservoirs, however, because of their relative large size and limited distribution, do not emulate the natural prototype.

Wetlands can have a decided but varied effect on suspended solids (Exhibit 2-6). These effects depend on the incoming concentrations, the depth of the wetland, the mean residency time, and wave and other disturbances (Kadlec and Knight, 1996). Whereas suspended solids are considered conservative (they are assumed not to change their chemical form as they move through or are trapped by wetlands), other constituents such as nitrate and nitrite are altered. In the anaerobic zones of wetlands, bacteria strip the oxygen from the nitrate and nitrite molecules, releasing nitrogen gas to the atmosphere. The removal of nitrogen in the wetland can be as great as those for suspended solids, as shown in Exhibit 2-6. The biochemical reactions, however, change with temperature. During warmer months, more $NO_3$ is converted to nitrogen gas, and the oxygen is consumed, as shown in Exhibit 2-7. During the winter, in regions of the United States where temperatures fall below freezing, the microbial reactions slow and the reduction of $NO_3$ is curtailed. Similar chemical and physical reactions control the cycling and fate of other nutrients and a wide range of organic contaminants, such as the herbicide atrazine (Exhibit 2-8).

The carbon cycle is affected by wetlands (Mitsch and Wu, 1995). Wetland plants, like other plants, remove $CO_2$ from the atmosphere and temporarily store it as living biomass. As the plants die and decompose, however, the carbon can be returned to the atmosphere or it can be retained on a more permanent basis. In shallow marshes, such as sedge meadows that dry out during periods of the year, a majority of the biomass may be oxidized and the carbon returned to the atmosphere. Wetlands that have sustained surface water tend to retain more carbon. Bogs and deep marshes are examples in which organic carbon is stored in the form of peat.

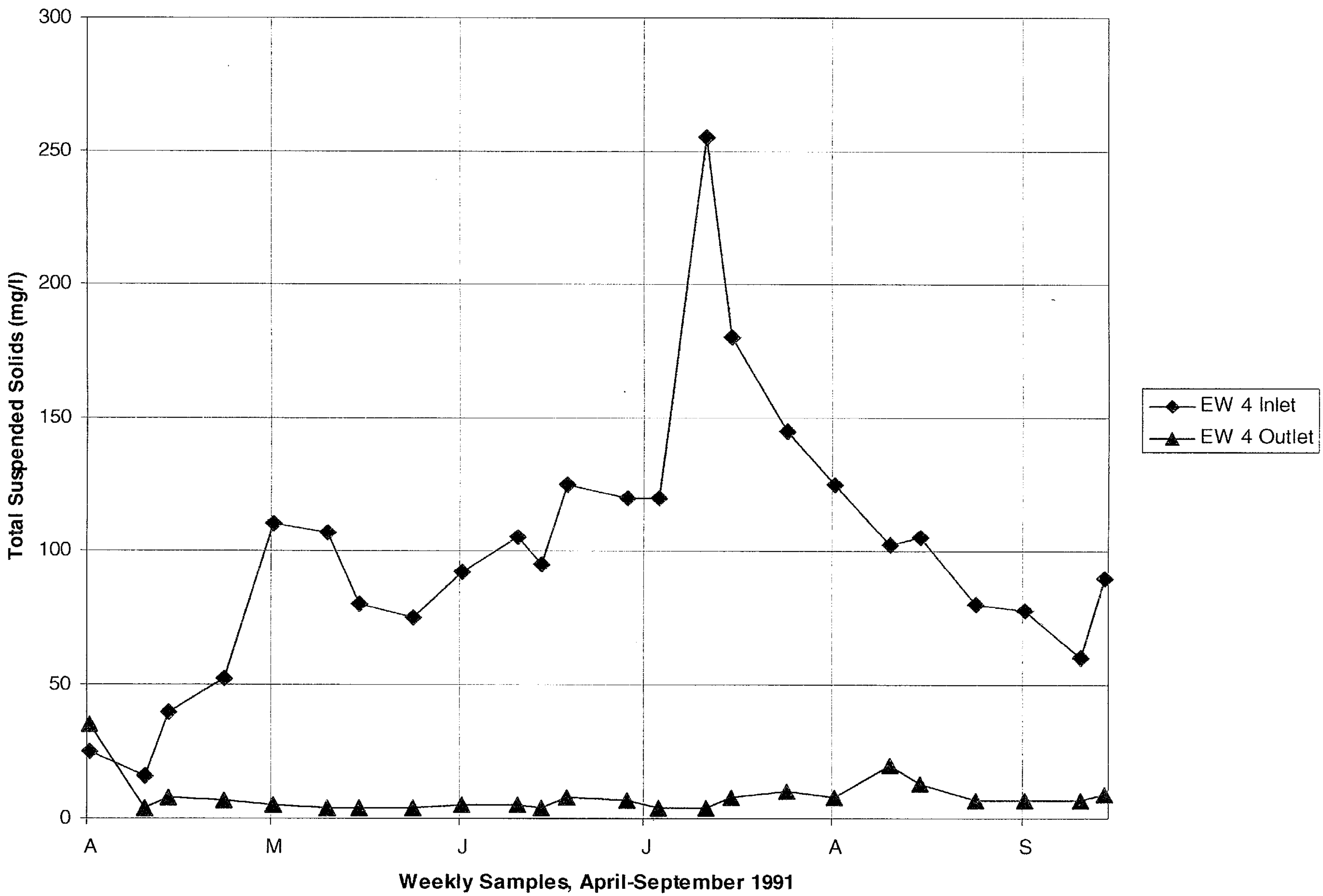



EXHIBIT 2-6: SUSPENDED SOLIDS REDUCTION BY EXPERIMENTAL WETLAND 4 AT THE DES PLAINES RIVER WETLANDS DEMONSTRATION PROJECT (by permission of Wetlands Research, Inc., Chicago, Illinois)

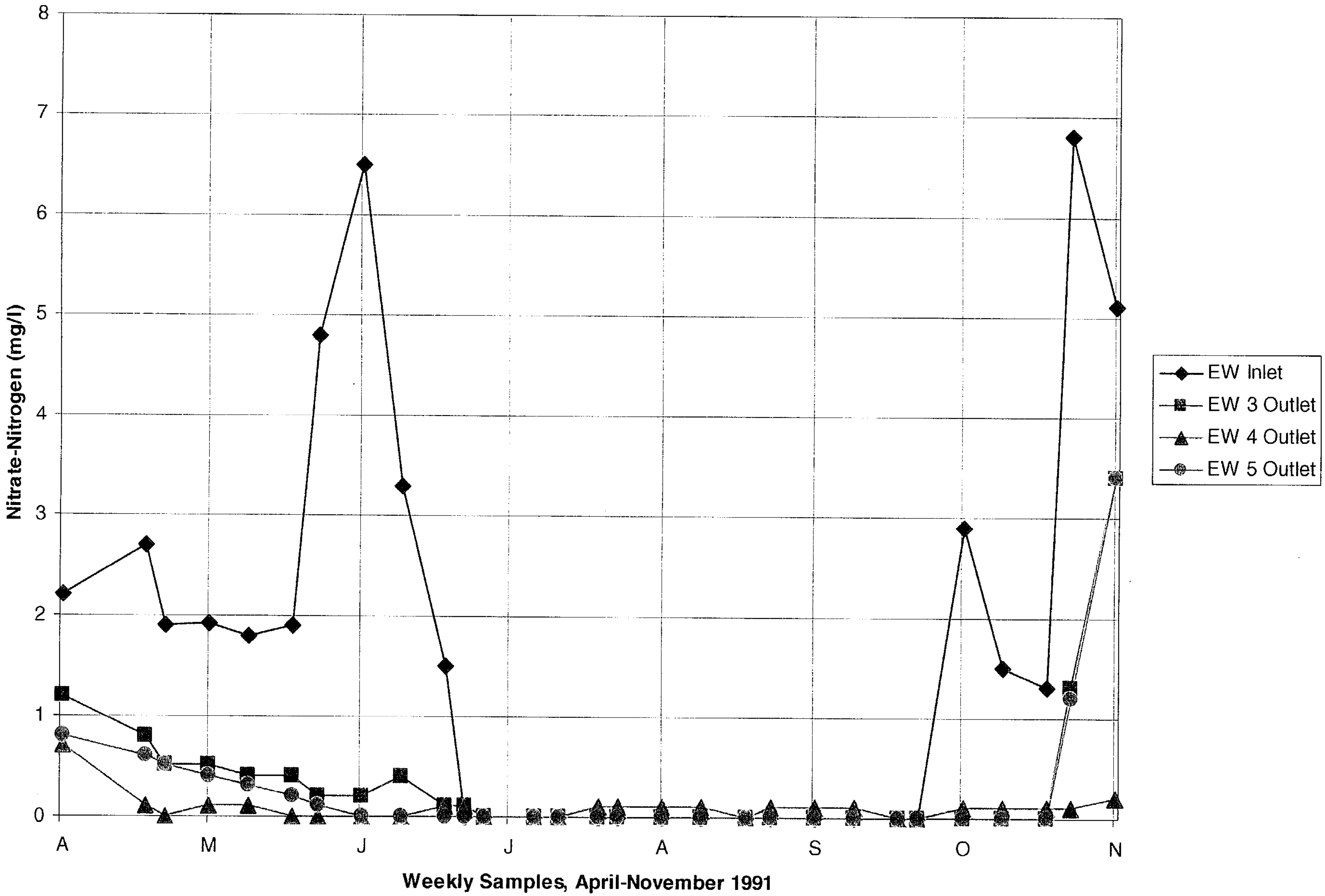



EXHIBIT 2-7: NITROGEN REDUCTION BY THREE EXPERIMENTAL WETLANDS AT THE DES PLAINES RIVER WETLANDS DEMONSTRATION PROJECT (by permission of Wetlands Research, Inc., Chicago, Illinois)

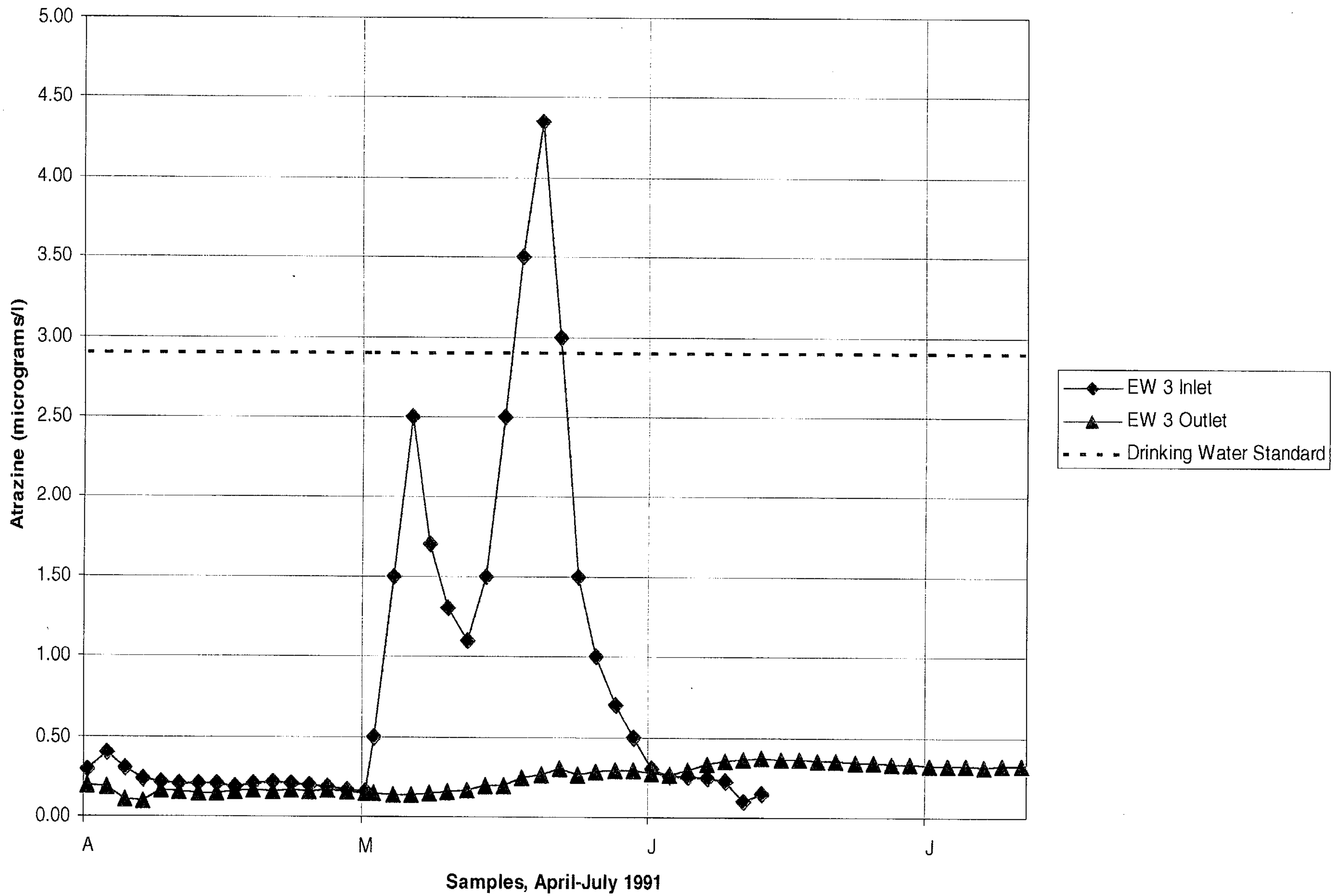



EXHIBIT 2-8: ATROZINE REDUCTION BY EXPERIMENTAL WETLAND 3 AT THE DES PLAINES RIVER WETLANDS DEMONSTRATION PROJECT (by permission of Wetlands Research, Inc., Chicago, Illinois)

Underneath the blanket of water, or in saturated conditions, biogeochemical actions begin the process of forming hydric soils. Landscape position can be far more important in deciding the character of soils than any other factor. In mountainous regions, soils tend to be coarser grained, containing cobbles and gravel, owing to the greater energy and carrying capacity of the stream; in flatter terrain the particle sizes are much smaller. Wetlands along coastal waters usually contain the finest materials of all, having been ground to very small particles during their journey to the sea.

The character of the underlying soils depends on the parent material, whether sandstone, limestone, or granite, and the period and duration of inundation. Regardless of the responsible factors, hydric soils can form very quickly. The characteristic processes, such as chemical reduction (e.g., ferric oxide is converted to elemental iron appearing as rust-like flecks in the soil profile) begin to work. Within 5 years, the indicators of hydric soils can be observed (Vepraskas et al., 1995).

Over the soil, adjacent to and in the water, hydrophytes grow and prosper. In association with each other and their physical surroundings, they form the habitat structure of the natural landscape. Wetland plants vary by landscape position, climate, geology, and hydrologic conditions. Water depth and duration of inundation are perhaps the most important determinants of plant community. Within climatic zones, regional lists of hydrophytes and their habitat requirements are widely available.

## CONCLUSIONS

The hydrologic, chemical, and biological reactions of wetlands vary only in degree from one landscape position to another. On the side of a mountain slope, a fen and the associated microbial populations act to alter the flow regimes and chemistry of the sustaining stream of water. In intertidal and tidal basins, the ebb and flow of freshwater and saltwater have diurnal effects on the depths and surface areas, but nonetheless support the growth of microbial communities that interact with the surface and interstitial waters. The creation or restoration of a wetland must combine these controlling factors in accordance with the type of wetland desired, the landscape setting, and the ambient climate--a task that may be easier said than done.

Most restoration projects in the United States are small-scale--from 0.4 - 0.81 ha (1 to 2 acres) to perhaps 6 - 8 ha (15 - 20 acres). The controlling factors can be applied or manipulated without fear of adversely affecting nearby vested uses, except perhaps for backing water up on someone else's property. With larger-scale projects, applied to a watershed, for example, and with projects intended to provide specific benefits, two concerns must be addressed:

1. How much wetland area is required to satisfy a given set of objectives?

2. Where should the wetlands be placed within the watershed and relative to each other?

Without specific details, only a general response to the first question can be offered. The greatest effects of restoring wetlands in the Midwest seem to occur when wetlands represent between 0 percent and 10 percent of the watershed area (Johnston et al., 1990; Hey and

Wickencamp, 1998). Beyond this range improvements still occur but at a much lower rate. Beyond 10 percent, the law of diminishing returns takes effect--yield, peak flows, and excursion frequencies are reduced to a lesser extent by each additional acre of wetland, while base flow is increased in the same fashion.

The answer to the second question is quite simple: as close to the point of need as possible. Ogawa and Male (1983), studying flood control on the Charles River in Massachusetts, clearly demonstrated and articulated the proximity rule. The further away the controlling storage is, the greater the opportunity for intervening flood flows to negate the hydraulic benefits of the lower stages brought about by the storage structure. Similarly, reducing biochemical oxygen demand far upstream from the point requiring sustained high levels of oxygen only permits the intervening demands to consume the extra oxygen provided by the upstream treatment capacity.

In addition to the issues of proximity and scale, each restoration project should be viewed as potentially contributing to the solution of downstream, larger-scale problems. Wetlands were removed from the natural landscape acre by acre causing the gradual, incremental degradation of the aquatic environment. A gradual restoration will result in a gradual, incremental improvement of many environmental characteristics.

Flood damage could be greatly reduced if wetlands, rather than farms, towns, and industrial facilities occupied flood plains. In 1993, floodgates that ravaged the upper Mississippi Basin could have been harmlessly and productively stored on 5.3 million ha (13 million acres) of wetlands. This area, in addition to the existing wetlands, would bring the total to 12.95 million ha (32 million acres) in the entire watershed, which would represent 7 percent of the watershed area and only 60 percent of the presettlement wetlands (Hey and Philippi, 1995).

Wetlands of all varieties along the waterways and in upland areas of the Mississippi watershed could help address the nitrate and silicate imbalance in the river's discharge to the Gulf of Mexico. The imbalance of these chemicals is thought to be causing the depletion of dissolved oxygen over an 18,129 square km (7,000 square miles) area, affecting shellfish and other aquatic life (Rabalis, 1996).

Project by project, wetlands can be reestablished on the landscape, natural or otherwise. As wetlands flourish and landscapes emulate the natural prototype, wildlife will proliferate and many of our Nation's environmental problems can be solved.

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# CHAPTER 3

## WETLAND RESTORATION: COMPENSATION FOR LOSSES

### THE NATIONAL POLICY FORUM

The Conservation Foundation convened a National Wetlands Policy Forum in the summer of 1987 out of concern that wetland losses were continuing, despite 15 years of regulatory protection under Section 404 of the Clean Water Act. In adopting its interim and long-term goals, the forum executed a strategy that had not been officially recognized in either the language of the Act or in the Section 404(b) guidelines that defined its intent–compensatory wetland mitigation.

Compensatory mitigation, henceforth referred to as "mitigation," is the restoration, creation, enhancement, or in exceptional circumstances, preservation of wetlands to compensate for unavoidable wetland losses (Lewis, 1989). By the end of the 1980s, mitigation was being commonly used by applicants for Section 404 permits to compensate for their destruction of existing wetlands. Without such mitigation, most wetland conservationists assumed it would be impossible to achieve either the forum's interim or long-term goals because permits have been issued regularly to allow the filling of existing wetlands. Although the only wetland loss data available to the members of the forum covered the period from the mid-1950s to the mid-1970s, data published in 1998, which reflected wetland losses between 1974 and 1983, proved this assumption to be correct.

### STATUS AND TRENDS OF WETLAND LOSSES

In 1982, the U.S. Fish and Wildlife Service (FWS) completed a National Wetland Trends Study (Frayer, 1983) that estimated the existence of 40.1 million hectares (ha) (99 million acres) of wetlands in the mid-1970s, reflecting a loss of 4.45 million ha (11 million acres) of wetlands since the mid-1950s. Subsequently, the FWS made corrections to that study, concluding that 42.9 million ha (105.9 million acres)--rather than 40 million ha (99 million acres)--of wetlands had existed in 1974. Using this new number, then, they calculated that an average of 185,350 ha (458,000 acres) had been lost annually between the mid-1950s and the mid-1970s.

Under the Emergency Wetlands Resources Act of 1986, which requires the FWS to update its inventory every 10 years, an assessment of wetland losses published in 1991 showed a further reduction of national wetlands to 41.8 million ha (103.3 million acres) by the mid-1980s. This loss of 1.05 million ha (2.6 million acres) of wetlands between 1974 and 1983 represented an average annual loss of 117,360 ha (290,000 acres). Thus, although average annual wetland losses had been reduced by 37 percent--from 185,326 ha (458,000 acres) to 117,360 ha (290,000 acres) in the decade following the passage of Section 404 in 1972, they still remained substantial. On the other hand, while certain types of wetlands, such as palustrine forested wetlands, suffered a loss of 1.38 million ha (3.4 million acres) during that time period, other types actually showed increases.

In response to a congressional mandate in the 1989 North American Wetlands Conservation Act, the FWS calculated and published, in 1990, an estimate of the total wetlands in presettlement America: 89.4 million ha (221 million acres) in the contiguous United States. Of those, 53 percent had been lost by the mid-1980s, leaving only 41.8 million ha (103.3 million acres) (Dahl and Johnson, 1991). Finally, in 1997, the FWS updated its status and trends reports, calculating an average of 47,350 ha (117,000 acres) of wetlands lost annually between 1985 and 1995. Thus, average annual wetland losses today have been estimated at 25.5 percent of what they were prior to passage of Section 404 of the Clean Water Act and the use of agricultural conservation measures such as "Swampbuster."

In comparison, a second Federal wetlands inventory is extrapolated from the Natural Resources Inventory (NRI) done by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA) in 1982, 1987, and 1992. It uses a different methodology from that employed by the FWS, but produces only slightly different results. The NRI estimated, for example, that between 1982 and 1992, the United States lost an annual average of 63,133 ha (156,000 acres) of wetlands.

That wetland losses are continuing at all has been challenged by one analyst (Tolman, 1997) who argued that wetland restoration efforts, mainly in volunteer programs, more than equaled the losses calculated by the NRI, and that there had actually been, in 1995, a net gain in wetland acreage nationwide of 27,924 ha (69,000 acres). Although critics of this analysis (Heimlich et al., 1997) have acknowledged that the Nation might, at last, be reaching the interim goal of no net loss, they and others have generally agreed that restoration statistics are at best incomparable to loss statistics and at worst totally misleading as representations of new wetlands created. The statistics that are generated by the voluntary restoration programs such as the USDA's WRP and FWS's Partners for Wildlife reflect acreage that are only wetland enhancements or improvements, or sometimes even non-wetland areas. Unfortunately, these numbers cannot be removed from the data in order to calculate the actual area of new, restored wetlands. Further, there is no commitment by these participants in voluntary programs to keep the lands indefinitely enrolled in the programs; thus, they have only a temporary status as wetlands. The WRP, for example, now requires the NRCS to enroll one-third of the restoration projects under annual contracts, one-third under 30-year easements, and only one-third under perpetual easements.

It has become clear, at this juncture, that the country is still experiencing some wetland losses, but that the rate of these losses has diminished dramatically since Section 404 of the Clean Water Act went into effect. Through both voluntary and compensatory restoration, particularly with ratios greater than 1:1 (restored: destroyed wetlands), there is the opportunity to achieve the forum's goal of no net loss in the near future, and even to meet the National Research Council's goal of an overall gain of 4.05 million ha (10 million acres) of wetlands by 2010 (National Research Council, 1992). That accomplishment will be meaningless, however, unless restoration actually produces functional equivalents of the lost wetlands. Although the language of public mitigation policy promises that the emphasis is on restoration of functions, mitigation is still a relatively new policy, one that was not explicitly anticipated by the U.S. Environmental Protection Agency (EPA) or the U.S. Army Corps of Engineers (COE) in the early days of Section 404.

## THE ORIGINS OF MITIGATION AS PUBLIC POLICY

Although mitigation is not mentioned in the 1972 CWA, the concept gradually achieved recognition in FWS policy, the COE regulatory program, and USDA programs. The EPA sponsored a report, at the end of the 1980s, that described the considerable advances that had been made in the science of restoration and compensatory mitigation (Kusler and Kentula, 1989). Finally, in a 1990 Memorandum of Agreement (MOA) between the COE and the EPA, mitigation became an official part of the Section 404 permit process.

Early on, mitigation was mentioned in the Fish and Wildlife Coordination Act, as amended in 1958, and in the National Environmental Policy Act of 1969 (NEPA). The Council on Environmental Quality (CEQ), in 1978 regulations issued for the implementation of NEPA, defined mitigation to include the following (Dennison, 1997):

1. Avoiding environmental impacts altogether by not taking an action (or part of an action) that might lead to environmental degradation;

2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation;

3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;

5. Compensating for the impact by replacing or providing substitute resources or environments.

The last of these five activities, compensation, or compensatory mitigation, is the accepted definition of wetland mitigation today and the one adopted in this report.

Mitigation has been used in the implementation of Section 404 since its inception. The FWS and the National Marine Fisheries Service (NMFS)--two Department of the Interior agencies with wildlife and fisheries habitat-protection missions--were given very little official influence on the Section 404 permitting process. This prompted them, in the view of one observer, to rely heavily upon mitigation to accomplish their own objectives (Kryzinski, 1989). When the FWS and NMFS could not prevent the COE's issuance of a permit to which they objected, they were able to achieve compensatory replacement for wetland losses. This was the process observed by William Kryzinski as he implemented the program in EPA's Region IV.

In 1981, the FWS promulgated a policy stating that mitigation can be considered for proposals that

1. Are ecologically sound;
2. Select the least environmentally damaging alternative;
3. Avoid or minimize loss of fish and wildlife resources;
4. Adopt all measures to compensate for unavoidable loss;
5. Demonstrate a public need and are clearly water dependent.

Compensatory mitigation was attractive both to the reviewing agencies and to the permit applicants because it vastly facilitated the onerous and time-consuming Section 404 review process; however, it was acceptable to the wetland protectionist community only to the extent to which it could effectively and predictably replace the lost wetland functions.

With attempts to restore and create wetlands during the 1970s began a body of evidence to support such effectiveness and predictability. In 1973, Congress had authorized the COE's Dredged Material Research Program, which assessed the feasibility of developing habitats on dredged materials substrate. Participants in an annual "Conference on the Restoration and Creation of Wetlands" had been demonstrating increased self-confidence in their craft since their beginnings as the "Conference on the Restoration of Coastal Vegetation in Florida," in 1974.

## WETLAND CREATION AND RESTORATION

In 1989, the EPA sponsored a symposium, "Wetland Creation and Restoration: The Status of the Science," and published the proceedings in two volumes. In an executive summary authored by John Kusler and Mary Kentula, some of the following points stand out in their discussion of the status of wetland restoration:

While hundreds of coastal estuarine mitigation projects have been constructed on the eastern seaboard, there are far fewer on the Gulf and Pacific coasts, and even less has been done to restore some kinds of inland wetlands. The most common and best known types of inland restorations are impoundments to create waterfowl and wildlife marshes, and the creation of marshes on dredged soil along rivers as part of the U.S. Corps of Engineers Dredged Material Program.

It appears to be most easy to restore estuarine, then coastal, and thirdly, freshwater marshes. It is more difficult to restore isolated marshes supplied by surface water, even more difficult to restore forested wetlands, and most difficult to restore isolated freshwater wetlands supplied by groundwater.

It has been difficult to evaluate success because often no goals are identified, and there is very little monitoring, either short- or long-term, to determine the outcome of the restoration activity.

In terms of the restoration of wetland functions, it is easiest to restore flood storage and conveyance functions; we're successful in restoring waterfowl production because we know so much about it; wetland aesthetics are easy for the visual effects and difficult in reproducing subtle ecological functions. There is substantial variation in our restoration of fisheries and food chain functions, depending on the specifics. Pollution control is relatively easy in removing sediments and more difficult in reducing toxics. As for groundwater recharge, we can't even assess it, much less recreate it.

Short-term successes are deceptive because vegetation may be difficult to sustain, long-term fluctuations in hydrology are common, excessive sediment builds up, and erosional equilibrium is tricky. The authors suggest that restorations may need midcourse corrections and long-term management including water control structures; replanting; regrading; buffers; barriers; controls on pollution and invasion; and periodic dredging.

## MITIGATION

The role of mitigation in satisfying the requirements of the Section 404 permit process was finally addressed formally in a series of memoranda in the early 1990s. On February 6, 1990, the EPA and the COE issued the first of these, an MOA concerning the "Determination of Mitigation Under the Clean Water Act Section 404(b)(1) Guidelines," applicable to individual permits. The memo listed the activities included in the CEQ definition of mitigation and suggested that they can be reduced to three categories: avoidance, minimization, and compensation. It affirmed the goal of "no overall net loss to wetlands," and pointed out that this goal "may not be achieved in each and every permit action" (Paragraph IIB). In other words, without compensatory mitigation, there cannot be "no net loss" of wetlands. The 1990 MOA addressed the controversial "sequencing" question by explaining that the COE first makes a determination that potential impacts have been avoided to the maximum extent practicable; remaining unavoidable impacts will then be mitigated to the extent appropriate and practicable by requiring steps to minimize impacts and, finally, compensate for aquatic resource values" (IIC).

What the 1990 MOA calls "compensatory mitigation" is defined as the "restoration of existing degraded wetlands or creation of man-made wetlands" but it also includes, in practice, enhancement, which upgrades the functions of all or part of an existing wetland. The "preservation" referenced in the 1990 MOA (sometimes referred to as "exchange") allows a 404 permit applicant to purchase or provide the money for the purchase of valuable wetland property to ensure its long-term protection, in exchange for the destruction of less valuable wetlands.

The MOA goes on to discuss avoidance first (IIC1), then minimization (IIC2), and finally, compensatory mitigation (IIC3) "required for unavoidable adverse impacts which remain after all appropriate and practicable minimization has been required." This latter section states that on-site is more desirable than off-site mitigation, that functional values lost should be considered in determining the compensatory mitigation, that in-kind is preferable to out-of-kind, and that wetland restoration should be selected over wetland creation, because "there is continued uncertainty regarding the success of wetland creation" (IIC3).

In addition, the MOA has a brief discussion of mitigation banking as "an acceptable form of compensatory restoration under specific criteria" (IIC3), a promise that additional guidance on mitigation will be provided, and an admonition that "preservation" or purchases "may in only exceptional circumstances be accepted as compensatory mitigation" (IIC3). In paragraph IIIB, the MOA says, "The objective of mitigation for unavoidable impacts is to offset environmental losses," and that it should provide "at a minimum, one to one functional replacement, with an adequate margin of safety to reflect the expected degree of success associated with the mitigation plan," adding that "this ratio may be greater where the functional values of the area being impacted are demonstrably high and the replacement wetlands are of lower functional value, or the likelihood of success of the mitigation project is low." Ratios for compensatory mitigation are typically in the range of 1-1.5 to 1 for restoration, up to 2:1 for creation, and 3:1 for enhancement, with higher ratios as perceived appropriate.

The 1990 MOA refers often to the replacement of functional values of wetlands. This condition can be met only if there is a satisfactory analysis of the functional values of both the lost and the replacement wetlands. Several methodologies have been developed to assess the functional value of wetlands, including the Habitat Evaluation Procedure (HEP) developed by the FWS and the Wetlands Evaluation Technique (WET) developed by the COE and the Federal Highway Administration (FHWA), U.S. Department of Transportation. The HEP has been in use by the FWS since the mid-1970s and was revised in 1980. It requires sophisticated analysis and formal training, the calculation of a Habitat Suitability Index (HSI) for each indicator species, and the measurement of site values and mitigation "credits" in terms of Habitat Units (HUs). The first version of WET--WET 1.0-- was developed in 1983 and modified as WET 2.0 in 1987, giving qualitative ratings of high, medium, and low for wetland functions in categories of effectiveness, opportunity, and social significance.

## MEASURING WETLAND IMPACTS

In the early 1990s, Congress, which was unhappy with the apparent subjectivity and lack of consistency in establishing mitigation requirements under the Section 404 regulatory process, directed the COE to develop a new, more quantifiable and consistent approach to assessing wetlands impacts and losses due to activities permitted under Section 404. Accordingly, the COE began development of a regionalized, state-of-the-science, approach to assessing wetlands functions and impacts based on hydrogeomorphic principles. This approach considered hydrologic regime, landscape position, geochemistry, and biotic factors in developing simple, descriptive, mathematical models to describe the variation in functional condition and capacity of specific wetlands types. These models were regionalized so as to be more consistent within a specific geographical area and localized wetland type.

It had long been recognized that general models or descriptions about how wetlands performed natural functions, such as embodied by WET, were too broad to reflect geographic differences in wetland types, functions, and values. The hydrogeomorphic approach to functional assessment of wetlands, or HGM, classifies wetlands according to topographic position in the landscape, and source and movement of water. For example, broad hydrogeomorphic wetlands classes include depressional wetlands, which are located in relatively small topographical depressions; fringe wetlands, which occur around the edges of large lakes and estuaries; and riverine wetlands, which occur on the active flood plains of rivers and streams. The models for HGM are based on the same concepts as the Habitat Evaluation Program of the FWS. The COE has published a National Action Plan for implementation of HGM (Federal Register notice, 62 FR 33607 (June 1997)), and regional models continue to be developed.

## COSTS OF RESTORATION

No one knows quite what the real costs of compensatory restoration are, nor even how to measure them. Private costs, calculated as those costs imposed upon a developer by the Section 404 regulatory process, have recently been estimated to be between $40,000 and $115,000 per acre (Vanderpool, 1998). Administrative costs of the Section 404 permitting program have been calculated to be $78 million in the single year of 1995, but there is no way to calculate the benefits, which would be the area of prevented wetland losses in that time frame. The USDA, on the other hand, has estimated the per acre administrative cost of the WRP program to be $70 per acre restored, with an additional $5 per acre to monitor each acre throughout its life.

## MITIGATION BANKING

The Clinton Administration's 1993 Wetlands Plan gave a strong endorsement to compensatory restoration and official White House support to the relatively new concept of mitigation banking. Mitigation banking creates off-site mitigation "credits" that can be purchased by permit applicants in lieu of implementing mitigation actions on their development sites. The "banking" takes the concept of restoration as compensatory mitigation and moves it a step further away from the original Section 404 objective of preserving and protecting existing natural wetlands.

The Clinton Wetlands Plan acknowledged that "restoring some former wetlands, that have been drained previously or otherwise destroyed, to functioning wetlands is key to achieving the administration's interim...and its long-term goal" and among its 12 major initiatives was an endorsement of the use of mitigation banks in order to "increase the predictability and environmental effectiveness of the Clean Water regulatory program." The plan described mitigation banking as the fourth step in the Section 404 review sequence, following avoidance, minimization, and on-site compensation when they are not appropriate, practicable, or as environmentally beneficial as the mitigation banking site.

The FWS had developed the concept of mitigation banking in the early 1980s, and an MOA authored by the COE and the EPA the day before the release of the Clinton Wetlands Plan addressed the applicability of mitigation banking to the Section 404 process (Dennison, 1997). The COE initiated the National Wetlands Mitigation Banking Study, and provided further elaboration and extension of the mitigation banking concept to a full range of Federal activities was provided in the Federal Register notice, 60 FR 58605 (November 28, 1995). These guidelines identified the COE as the lead agency for mitigation banking with the exception of those banks proposed solely to comply with Swampbuster, which would be reviewed by the NRCS.

The Federal Register notice set the goal of providing economically efficient and flexible mitigation opportunities while at the same time including "the need to replace essential aquatic functions which are anticipated to be lost through authorized activities within the bank's service areas." In selecting the sites for mitigation banks, agencies were asked to ensure that they possess the "physical, chemical, and biological characteristics to support establishment of the desired aquatic resources and functions. "Compatibility with adjacent land uses and watershed management plans" were identified as "important factors for consideration."

Mitigation banks were at first developed exclusively by single user public entities to offset their own mitigation requirements, but gradually private (non-applicant) entrepreneurs began to develop what are seen as market-based banks. Proponents argue that banks will reduce and resolve the problems associated with project-specific compensatory mitigation and that they provide an excellent vehicle for incorporating mitigation into watershed planning. Opponents fear that banks will be used even more than project-specific off-site mitigation as easy and inadequate alternatives to the hard work of avoidance and minimization of impacts on wetlands. By early 1998, there were close to 200 approved wetland mitigation banks in existence.

## THE LIMITATIONS OF MITIGATION

Through the use of mitigation and mitigation banking, the implementation of our wetland protection programs has come to rely heavily upon the ability of wetland creation, restoration, and enhancement techniques to compensate fully for lost wetland functions. Scientists and regulators working in the field continue to express strong reservations, however, about the effectiveness of these techniques. The difficulties seem to fall into the following categories:

1. ***TECHNOLOGY***--There are still technical difficulties in compensating for the functions of certain wetland types such as bogs, fens, or those supporting old growth forests; for example, cypress swamps and bottomland hardwood forests in the lower Mississippi River Valley. In some cases, instrumentation or apparatus is not available for tasks at hand, or is difficult to use. Trained and experienced wetland ecologists are not readily available. Construction techniques are sometimes inadequate or too imprecise. The functional characteristics and values of specific wetland types are not fully understood or adequately valued in many cases, and the regulatory process is not sufficiently prepared and funded to take these issues into account.

2. ***PROCEDURAL AND ADMINISTRATIVE CONSTRAINTS***--There are laws and regulations which limit the ability of agencies to restore or create wetlands. Limits on personnel, authority, or procedures to acquire appropriate mitigation/restoration sites and subsequent management infrastructure for restored wetlands are all barriers to meeting national goals for wetland restoration and conservation.

3. ***TIME***--Many wetland types take long periods of time to develop and mature, such as forested bottomland and oligotrophic bogs. The time frames of regulatory and management programs are inadequate to manage restoration over the time required for success to be properly evaluated.

4. ***FUNDING***--Managing and mitigating wetlands takes money. Financial incentives are not present to optimize funding of wetlands restoration and replacement programs or projects. The general approach is to meet regulatory mitigation requirements at minimal financial cost to the permittee. Agency funding does not meet resource management needs. This does not result in optimum conditions for successful wetland mitigation and management.

5. ***ECOLOGICAL PROCESSES***--We are not able to control the natural environment. Invasion by exotics plants is a common problem in wetland creation/restoration. We now have many exotic plant and animal species which were not even in the United States at the beginning of the twentieth century. Likewise, we are not able to duplicate the successional processes or stages through which many of these wetlands passed on their way to their present state. Also, landscape characteristics, and possibly even our climate, have changed over time and are no longer representative of conditions which were present 100, 1,000, or 10,000 years ago, when many of our wetlands were created.

## WETLANDS MITIGATION IN THE CONTEXT OF WATERSHED PLANNING

Concurrent with the developing national interest in wetland restoration is a growing emphasis within the resource agencies, and the EPA in particular, on making water resources management decisions within the context of the total needs of individual drainage basins. This watershed planning approach, if done well, has the potential to solve many of the major difficulties encountered in compensatory mitigation. Mitigation banks, in fact, have been seen as the very mechanism by which wetland mitigation will be successfully incorporated into such plans. Although the proper and successful implementation of watershed planning requires a level of technical and administrative expertise that is rare, its achievement may allow us to reach*genuine* "no net loss" and perhaps even long-term net gains in wetland values and functions.

Different Federal agencies and programs have acknowledged the value of planning in the broadest possible context, by different routes. The EPA has established the watershed as the geographic unit within which to control nonpoint source pollution and published, in 1991, *The Watershed Protection Approach*. In February 1995, it produced a "Fact Sheet on Wetlands and Watersheds" (EPA, 1995) that suggests looking at the whole system--land, air, and water--to develop management plans for aquatic resources. In 1996, it published a Watershed Approach Framework. The White House Office on Environmental Policy established, in 1993, an Interagency Ecosystem Management Task Force, and the four agencies who are responsible for Federal ownership of about 30 percent of our total national land surface area--the National Park Service, the Bureau of Land Management, the FWS, and the USDA's Forest Service--are developing ecosystem approaches to their land and natural resources management (U.S. General Accounting Office, 1994). The NRCS in the USDA has established ecosystem-based management of natural resources. Local planning bodies have adopted subwatershed and regional approaches. The COE's Special Area Management Plans (SAMPS) and the EPA's Advanced Identification (ADID) process share some of the attributes of watershed planning, as well.

Watershed planning has sometimes been "single purpose" and has not always included wetland preservation and restoration components. Good watershed approaches to environmental planning and management, according to the EPA, contain 1) strong partnerships with stakeholders; 2) a geographic focus and management techniques based on sound science and data; and 3) coordination of a wide range of programs including drinking water source protection, waste management, point and nonpoint source pollution, air pollution, pesticide management, and wetlands protection.

In the introduction to a 1995 publication containing a wide range of papers on wetlands and watershed management (Kusler, 1995), principal editor Jon Kusler has made it clear that the most important feature of a watershed planning context is the inclusiveness of the water and landscape regimes. In that context, Kusler says, the role of wetlands in relation to water quality, flood storage and conveyance, wildlife and fisheries habitat, and recreation can be assessed.

## SOLUTIONS FOR WETLAND PROTECTION PROGRAMS

Kusler believes that the following problems currently plaguing wetland protection programs can be resolved by adopting the watershed approach:

1. Unsuccessful restorations because of lack of control over outside influences on water quantity and quality;

2. Failure to identify wetlands functions in relation to other parts of the landscape and water regime;

3. Failure to recognize cumulative negative impacts on wetlands;

4. Unresolvable conflicts with other water resources management objectives and programs;

5. Inability to identify optimum restoration sites;

6. Inability to identify wetland functions;

7. Hydrologically failed projects.

<u>Good watershed-based planning, according to Kusler, includes the following components:</u>

1. Identification of specific problems and needs;

2. Involvement of all the key players;

3. Scientific understanding of the key relationships between wetlands and water regimes;

4. Specific wetland/ecosystem goals;

5. Good mapping;

6. Analysis of the relationship between wetlands and other elements;

7. Major involvement by locals;

8. Consideration of implementation techniques "up front";

9. Involvement of all--not just wetlands--water resources managers.

Although both the EPA's and Kusler's criteria for successful watershed-based programs are well beyond our present institutional capabilities, many States and regional agencies are taking the first steps toward their accomplishment. In Massachusetts, the Executive Office of Environmental Affairs established, in March 1994, a Wetlands Restoration and Banking Program to tie compensatory restoration and mitigation banks to overall watershed deficits and needs. Twenty-eight watersheds have been identified, within which the State Water Resources Agency is 1) identifying restoration sites; 2) identifying watershed needs and goals; and 3), screening the sites for their potential to contribute to those goals. By early 1998, the Executive Office had completed a draft plan for one of the 28 watersheds--Neponset–which flows into Boston Harbor from the south. Watershed needs and deficits had been defined, more than 160 potential restoration sites (individual, not banking sites) were identified, and finally, the community had been involved in the establishment of 7 goals for the watershed and the selection of 40 priority sites (Foote-Smith, 1998).

In the Puget Sound region of the State of Washington, two State agencies--the Department of Ecology and the Department of Transportation (WSDOT)--are attempting to create watershed-based programs, in separate efforts, to drive their wetland restoration programs. The region contains 18 river systems which, in turn, contain approximately 200 watersheds. The Department of Ecology has recently completed the development of a Wetlands Restoration Plan and the establishment of a database for one of these river basins, the Stillaguamish. The planning document defines river basin problems, identifies wetland functions that address those problems, locates potential wetland sites, characterizes the wetland potential for providing key functions, assesses the restoration potential of the identified sites, and establishes a qualitative rank for each function. The Stillaguamish database provides a detailed description of wetland restoration sites and the functions each has the potential to provide, if restored.

The second State effort is the development, by the WSDOT's Environmental Program, of a watershed approach to the selection of wetland mitigation alternatives and the employment of wetland banking as an alternative to the traditional project-specific siting. The new approach is being applied to mitigation project development in the Snohomish watershed, another of Puget Sound's 18 river basins. Neither of these programs have been used yet on site mitigation projects.

## SUCCESS CRITERIA FOR WETLAND RESTORATION

Wetland mitigation and mitigation banking have become essential ingredients in our national wetland policy and regulatory programs today. The first, most important, step in the mitigation planning process is to understand what we want it to accomplish; in other words, to define the criteria for success.

To successfully mitigate wetlands losses, restoration projects must replace the important functions that were impacted. Where the understanding of those functions or the technology to replace them is lacking, impacts should be avoided or minimized to the greatest extent practicable. In determining the degree to which the understanding and the technology are available, the following questions could be asked first, based on J. J. Ewel's 1987 suggestions (Ewel et al., 1987), which are quoted in the Wetlands chapter of the National Research Council's 1992 *Restoration of Aquatic Ecosystems*:

1. Can we sustain the restored ecosystem?
2. Can we avoid invasion by exotics plants (and animals)?
3. Can we generate plant and animal productivity similar to a natural counterpart?
4. Can we retain nutrients?
5. Can we cause biotic interactions similar to those of reference systems?

If we can do these things at all, then we can identify specific success criteria for each ecological objective; that is, spell out the indicators of the ecosystems we want to protect, the exotics we want to repel, the productivity we will expect from our restored environment, the level of nutrient retention we hope to achieve, and the specific biotic interactions we intend to stimulate.

Hydrologic criteria must also be established, criteria for such functions as groundwater recharge, shoreline stabilization, flood-peak reduction, tidal flow restoration, resilience during hydrologic and climatic fluctuations, erosion control, and wave action reduction. Criteria relative to soils, their texture, and their organic content may be important. Some sites may provide opportunities for educational, aesthetic, or recreational goals to be met, and others may require resistance to human disturbances. Each criteria set will be specific to the individual project.

Where compensatory restoration appears to be possible, and realistic goals (success criteria) have been established, it would then be necessary to do the following:

1. Assess the structural and functional attributes of the wetlands being destroyed in a watershed context.

2. Set project-specific success criteria tied to those attributes (see above).

3. Select a mitigation site with the best potential for satisfying those criteria.

4. Establish a schedule for frequent monitoring for accomplishment of those goals and a mechanism for making changes, both during the construction of the restoration project and for a period of time after its completion.

5. Do a rigorous project evaluation in terms of the previously identified success criteria after project completion.

What this means, simply, is to do the planning in a broader context than is usually done, to be flexible as the project develops, and to extend the monitoring beyond the usual cutoff points. If intelligent, well-trained people on both sides of the regulatory bargaining table give thoughtful consideration to each of these steps, are flexible enough to make changes as they progress, and have the time and money to follow the project into the future, we may quite comfortably meet our strategic wetland policy goals.

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# CHAPTER 4

## FLORIDA KEYS BRIDGE REPLACEMENT

### LOST VEGETATION

In 1976, the Florida State legislature authorized the Florida Department of Transportation (FDOT) to replace the bridges that connected the string of islands off the southern tip of the State known as "the Keys." It was generally agreed at the time that the condition of these 41 bridges made travel from Miami to Key West along U.S. Highway 1 unreasonably slow and that their structural deterioration made it dangerous as well. The National Environmental Policy Act of 1969 (NEPA) process resulted in a negative declaration. The U.S. Army Corps of Engineers' (COE) permitting process--Section 404 of the Federal Water Pollution Control Act (FWPCA)--was not yet fully operational. The FDOT had to obtain Florida State water quality and dredge and fill permits from the newly created Department of Environmental Resources (DER).

Eventually, interagency discussions focused on specific questions: 1) the alignment of the new bridges; 2) whether new bridges or fill with culverts should replace the old bridges; 3) how to avoid the destruction of mangroves and sea grass communities; 4) habitat losses, water quality degradation; 5) reduction in water exchange between the bodies of water on either side of the Keys; 6) and where to put the dredged material. Although the concept of mitigation for environmental damages was relatively new, it eventually became part of the dialogue.

On December 13, 1976, the FDOT and the DER finally crafted an agreement in which they negotiated design changes, agreed upon construction and disposal techniques, and endorsed mitigation requirements. The agreement required 1) turbidity controls during construction, 2) compensatory plantings of mangroves, and 3) a procedure by which sea grass losses might be mitigated. It was incorporated into the DER permits and, subsequently, into the 404 permits that were eventually required. With the signing of the agreement, the way was clear for the construction of the bridges. In 1978, the permits were issued and construction began. By 1982, all 37 bridge replacements had been completed.

Accomplishing the mitigation was difficult. Lost mangrove and sea grass communities had to be replaced, and the approaches to the bridges had to be revegetated. Once the mangrove plantings were underway, it was clear that there was insufficient right-of-way to accomplish the required amount of mitigation. FDOT personnel began a search for additional sites under public ownership. The opportunity to test a new concept was discovered on Bahia Honda Key, where tidal connection to an interior lagoon had been severed. The FDOT made a cut to restore tidal circulation and, subsequently, when the revitalization of the lagoon's ecosystems appeared to be underway, they installed culverts at three locations on Boca Chica Key to provide for tidal circulation that was expected to restore and expand a much larger area of mangroves.

Very little was known, at the time, about sea grass restoration techniques. As a result, the FDOT eventually wrote a check to the DER for the cost of restoration in lieu of providing compensatory sea grass plantings. The DER, in turn, contracted with a private consultant to conduct workshops that did some experimental plantings of turtle grass (*Thalassia testudinum*) in the damaged areas. Another effort to mitigate environmental damages was the seeding of those slopes on the bridge approaches where natural revegetation was not occurring.

In 1993, the FDOT funded an evaluation of the project mitigation activities, which was documented in a publication the following year. This study found that the tidal exchange accomplished by the installation of the Boca Chica culverts had revitalized the interior lagoons, resulting in substantial enhancement of mangrove communities and the appearance of new sea grass meadows (Lewis et al., 1994). Although earlier documentation made it difficult to provide complete comparisons, observations and photographs taken in 1993 recorded the successful development of fill-slope revegetation and shoreline mangrove plantings at many of the bridge locations. Therefore, the 1993 survey was able to report this satisfactory compensatory restoration of both the sea grass and the mangroves that had been lost because of the bridge replacement project.

## THE KEYS' ENVIRONMENTAL AND GEOGRAPHIC SETTING

The Florida Keys are exceptional in the complexity and diversity of the natural environments they contain and in the fragile and highly productive coral bank reef that parallels them on the ocean side. The Keys are a limestone island archipelago extending approximately 300 kilometers (km) (190 miles) southwest from the southern tip of Florida to the Dry Tortugas (see Exhibit 4-1). They are made up of more than 1,700 virtually flat islands, of which a small portion are inhabited.

The Keys are located at the southern edge of the carbonate platform known as the Florida Plateau, onto which sedimentation has been occurring for 150 million years. The 7,000-m- (23,000 foot) thick plateau is underlain by the crystalline and sedimentary basement rocks of the South Florida Basin, a block-faulted feature associated with the breakup of North America and Africa during the Mesozoic era. The region's current morphology is attributed mainly to sea level fluctuations caused by Pleistocene glaciations, terminating with the increase in sea level that permanently covered the area during the Wisconsin glaciation about 6,000 years ago.

The Upper and Middle Keys are a 120,000-year-old former coral reef that extends below Miami, Florida Bay, and the Dry Tortugas and surfaces from Soldier Key to the Newfound Harbor Channel. The reef is composed of Key Largo limestone, is from 23 to 52 meters (m) (76 to 172 feet) thick, and has high porosity and permeability. The Lower Keys are broad and flat, separated by narrow channels with their axes perpendicular to the axis of the chain of islands. The Lower Keys are composed of Miami oolite, a series of fossilized sandbars that developed concurrently with the Key Largo limestone and, beginning at Big Pine Key, overlie it. Though also highly porous, the oolite is much less permeable than the limestone. Surface sediments are mainly marine calcareous sands. Peat is sometimes found in depressions, and limy marls occur infrequently (Kuyper, 1979).

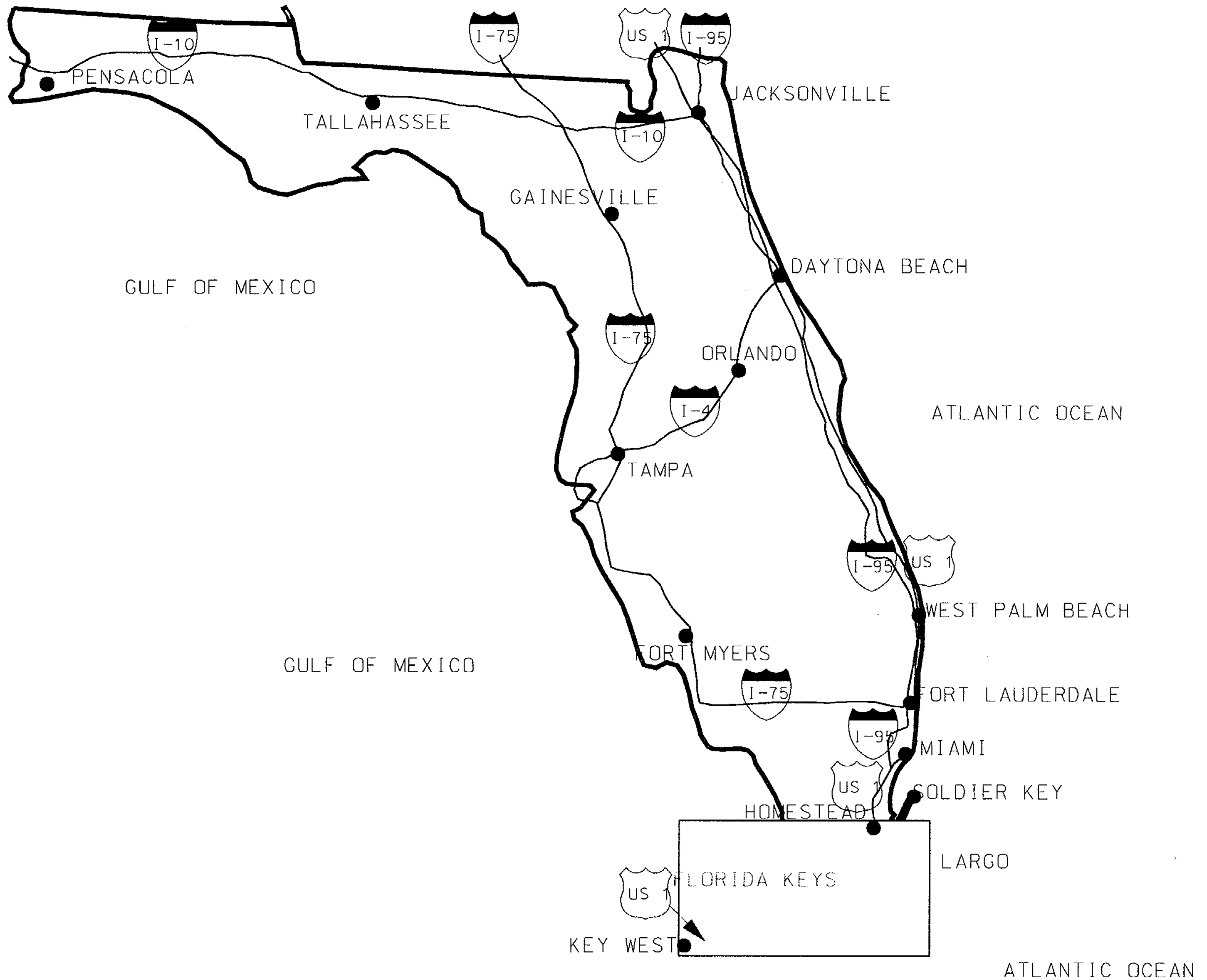



EXHIBIT 4-1: PROJECT LOCATION

The triangle of water between southern Florida and the Lower Keys is called Florida Bay (Exhibits 4-2a and 4-2b), a shallow area spanned with mud flats composed mostly of calcium carbonate. The Bay experiences wide fluctuations in temperature and salinity and periods of high turbidity. On the opposite, southeast side of the archipelago is the Atlantic Ocean and the Florida Reef Tract, a series of living coral bank reefs that parallel the Keys themselves.

The Florida Reef Tract is located on a narrow shelf that drops off, further out, into the Straits of Florida. This tract comprises one of the largest communities of its type in the world: bank reefs extend for 130 km (81 miles) from the Marquesas to near Miami and are edged with approximately 6,000 patch reefs. The warm nutrient-deficient waters resulting from the tidal exchange with the Atlantic Ocean are important to healthy reef development.

> "Both patch and outer reefs maintain a balance between physically constructive elements (including corals, algae, and other flora) and destructive elements (e.g. salinity and water temperature changes, turbidity due to weather events, exposure to air, and changes in nutrient levels). By altering the physical characteristics of the reef environment, human activities may further stress an already stressed ecosystem."
>
> --the National Oceanic and Atmospheric Administration (NOAA), 1995 (through Jaap and Hallock, 1990; Voss, 1988)

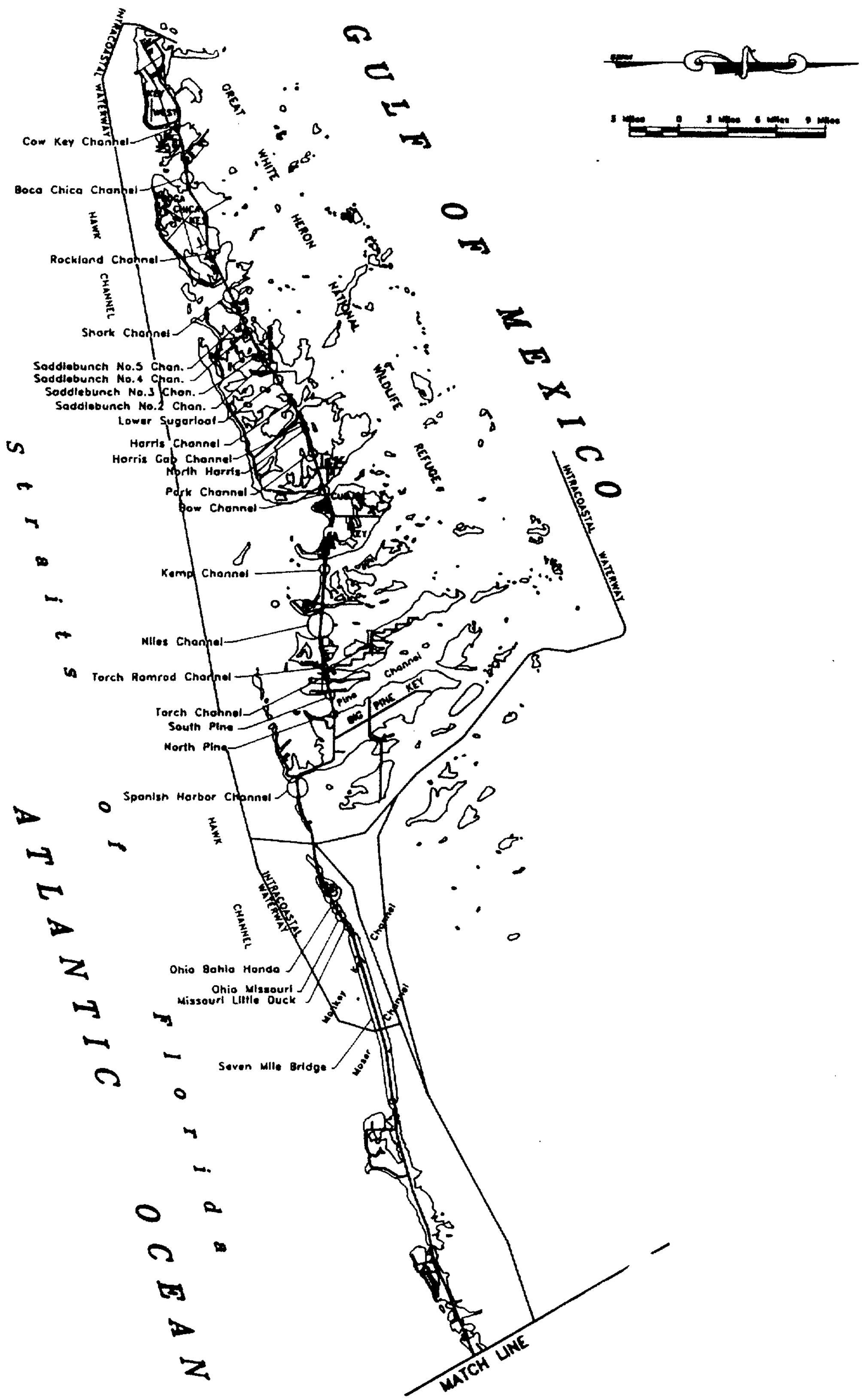



EXHIBIT 4-2a: LOWER KEYS BRIDGE LOCATIONS (USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM <u>WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994)</u>

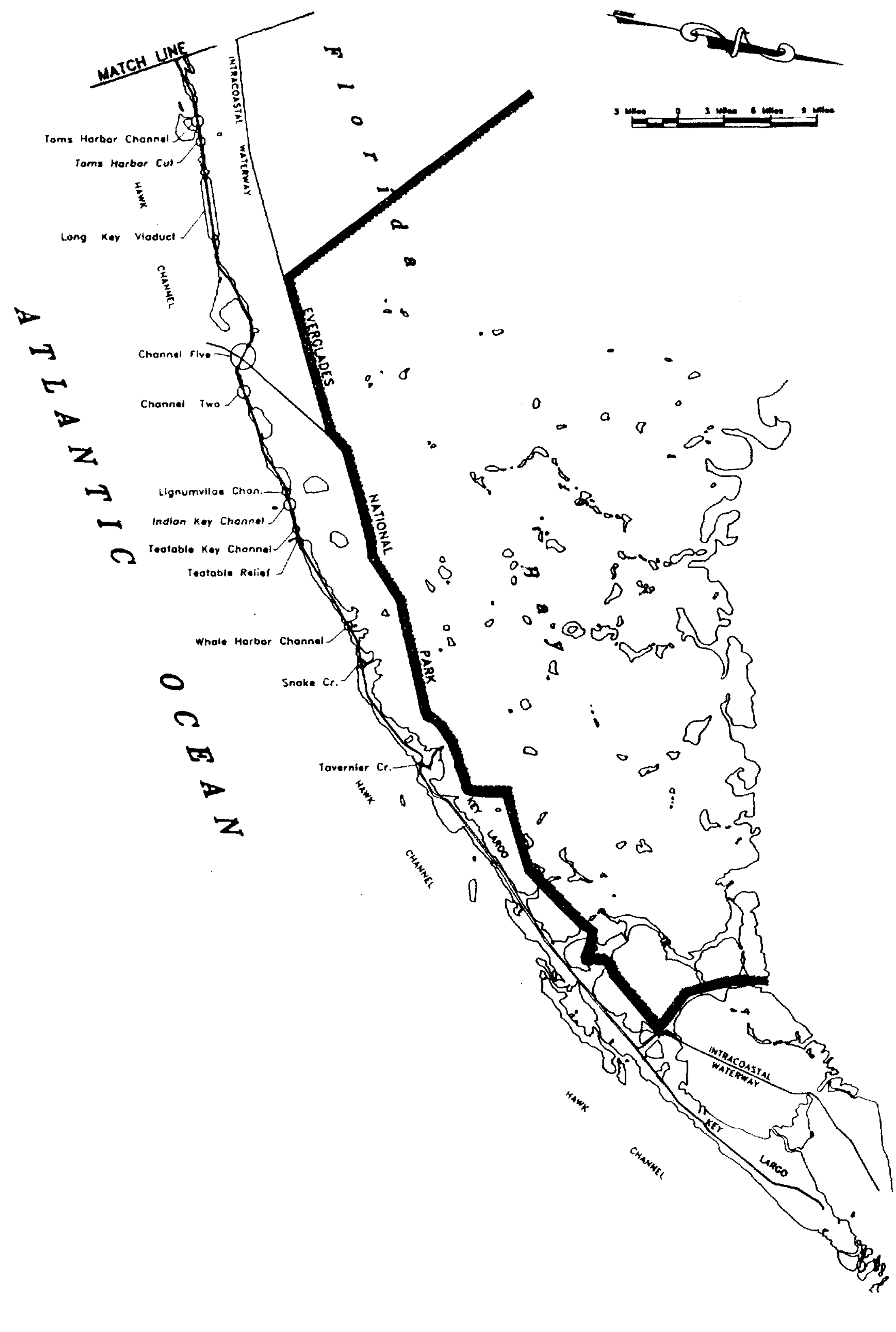



EXHIBIT 4-2b: UPPER KEYS BRIDGE LOCATIONS (USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM <u>WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994)</u>

The Florida Reef Tract is separated from the islands of the Keys by Hawk Channel (see Figs. 4-2a and 4-2b), which itself contains a coral reef and its biotic communities. Movement of nutrients, sediments, and salinity through the channels between the Keys occurs primarily in the direction from the bay to the ocean side as the warmer bay water flows outward through the channel. Reef development is greater off the Upper and Lower Keys than off the Middle Keys.

Circulation of waters along the Atlantic side of the Keys is dominated by the west to east Loop Current which, entering the Gulf of Mexico from the southwest, loops north and clockwise and exits southwest of the Dry Tortugas to become the Florida Current, traveling along the State's east coast in a northerly direction. This water movement typically produces*gyres* along its path, counterclockwise currents of cold water that have been observed to trap nutrients along the bank reefs near the Lower Keys and provide flushing to the reefs of the Upper Keys (NOAA, 1995). The warm waters of the Florida Current are essential to the survival of the Florida Reef Tract.

The little rain that falls in the Keys is quickly absorbed into the porous rock formations and ends up in shallow lenses, most of which are brackish. There are no freshwater springs on the Keys, although a few of the larger islands have fresh water in lagoons and subsurface lenses. Groundwater in South Florida and the Keys consists of both these lenses and the 50 to 300-meter (500 to1000-foot) deep Floridan Aquifer, which underlies not only Florida but also portions of Georgia, South Carolina, and Alabama. The groundwater in this aquifer system ranges from brackish to seawater, and it is used mainly for subsurface storage of liquid wastes.

**THE KEYS' WEATHER PATTERNS**

The region has a tropical maritime climate with moderate temperatures and two seasons: a long, wet summer extending from May to October, and a mild, dry winter from November to April. The circulation patterns of the Florida Current and Gulf Stream influence the climate, as do also the warm waters of the Gulf and the Atlantic Ocean. The weather is associated with the tropical maritime air of the Bermuda/Azores high pressure system, and tropical storms and hurricanes are typical features. The annual probability of a hurricane occurring is between 13 and 16%, and Key West has averaged one hurricane every 8 years. The 1935 Labor Day storm in the Keys was the most violent to have made landfall in the United States and is one of only two Class 5 hurricanes ever to have hit the United States. Winds are from the east-southeast during the summer and the east-northeast during the winter. The flatness of the terrain makes the Keys particularly vulnerable to the damage of hurricanes; 96 percent of the land mass is less than 2 m (6.6 feet) above sea level and the highest elevation, on Windkey Key, is only 5.5 m (18 feet). Storm surges, produced as underlying water domes up in response to low air pressure and combines with high wave action, are considered the greatest threat to the Keys. The Lower Keys have the Nation's greatest frequency of waterspout occurrence.

Precipitation across the Keys is lower than in the rest of Florida, greatest in September (16.5 cm (6.5 inches) monthly mean and least in March (3.3 cm (1.3 inches)), with an average annual rainfall of 124.5 cm (49.1 inches). Most rainfall occurs in the form of the intense summer storms. Temperatures are the most moderate in the State, varying little either across the Keys or throughout the year. Temperatures in Tavernier and Key West are typically within 1°C of each other. Average annual temperatures at Key West vary from a maximum of 28°C to a minimum of 23°C. The mean average annual relative humidity is 75 percent and remains constant throughout the year. Droughts are most likely to occur during May, June, September, and October.

## THE KEYS' ECOSYSTEMS

The Keys' ecosystem is considered to be ecologically and aesthetically unique within the United States and is part of a wider system described as "one of the most complex ecosystems on Earth" (NOAA, 1995). The larger ecosystem ties the near shore habitats and tidal channels of the islands themselves to the ecosystems of the lower Everglades, Florida Bay, the Gulf of Mexico, and the Atlantic Ocean. The near shore habitats, including the important mangrove and sea grass environments, provide shelter, food, and nurseries for many of the species of the broader area. In addition, the human activities on the Keys, including such infrastructure projects as the Key Bridges Replacement, have substantial impacts on water quality, specifically upon the clarity of water so critical to the Florida Reef Tract offshore.

A wide range of habitats are available on the Keys themselves, including beaches, coral reefs, sea grass meadows, pine rockland, transitional wetlands, freshwater wetlands, and mangrove and hardwood hammocks. Two distinct marine habitats can be observed on either side of the archipelago: the Gulf of Mexico's warm-temperate habitat in the Florida Bay and a tropical Caribbean habitat on the Atlantic side, with an ecological and biological mixing zone in the near shore area of the islands themselves. The Florida Reef Tract comprises one of the largest communities of its type in the world. In addition to the bank reef habitat, it includes offshore patch reefs, sea grass, back reefs, bank reefs, intermediate reefs, deep reefs, outlier reefs, and sand and soft bottom.

## THE KEYS' ENDANGERED OR THREATENED SPECIES

Seventy-one species of plants in the Keys are listed as threatened or endangered by the Florida Department of Agriculture and Consumer Services (FDA). The U.S. Fish and Wildlife Service (FWS) has listed two species as endangered under the Federal Endangered Species Act--Key tree cactus (*Icereus robinii)* and Small's milkpea *(Galactia smallii*); and one as threatened, Garber's spurge (*Euphorbia garberi).*

Among the animals that have been classified as threatened or endangered by either the Federal or the Florida Governments are the following:

1. Invertebrates: Florida tree snail, the Stock Island tree snail, the pillar coral, Schaus's swallowtail butterfly

2. Fishes: the common snook, Key blenny, Key silverside, and mangrove rivulus

3. Amphibians and reptiles: the American alligator and the American crocodile; the Atlantic green, Atlantic hawksbill, Atlantic loggerhead, Atlantic Ridley, leatherback, and striped mud turtles; the Big Pine Key ringneck, eastern indigo, Florida brown, Florida ribbon, Miami back-headed, and red rat snakes; and the Florida Keys mole skink

4. Birds: the American kestrel, American oystercatcher, Arctic peregrine falcon, Bachman's warbler, brown pelican, burrowing owl, Cape Sable seaside sparrow, Florida sandhill crane, least tern, little blue heron, snowy egret, tricolored heron, osprey, piping plover, reddish egret, roseate spoonbill, roseate tern, southeastern snowy plover, white-crowned pigeon, and wood stork

5. Mammals: blue, fin, humpback, right, sei, and sperm whales; Florida manatee; Key deer; Key Largo cotton mouse; Key Largo wood rat; silver rice rat; and Lower Keys marsh rabbit

## PROJECT BACKGROUND

Land access to the Keys is restricted to a single highway--U.S. 1--the Overseas Highway, which links the islands together by a series of 42 bridges between Homestead, on the mainland, and Key West, the furthermost populated island. Today, only 51 of the 1,700 islands in the Keys are connected to or by U.S. 1. Built in 1946, the bridges had, by the 1970s, deteriorated sufficiently that repairs and maintenance were costing the FDOT as much as their replacement; therefore, in the early 1970s, the FDOT developed a plan to replace them The two reasons put forward by the FDOT were 1) safety (people were actually afraid to drive on some of the bridges, and the drawbridge span on Seven-Mile Bridge got stuck frequently) and 2) ease of evacuation in case of a hurricane. The FDOT did not perceive replacement as a development issue because the two-lane bridges were not being enlarged. The Florida legislature authorized the Keys Bridge Replacement Program at an estimated cost of $175 million in 1976. Because so many bridges were involved, the concerned State and Federal agencies agreed early on that negotiating the conditions of the necessary environmental permits would be done as a single program, albeit individual permits were eventually issued for each ofthe 37 bridges to be replaced. Ultimately, the environmental permits were conditioned on the relatively brief requirements contained in a Memorandum of Agreement (MOA) signed by the FDOT and the DER on December 13, 1976.

## PERMITS

The FWPCA, which authorized the COE's Section 404 dredge and fill permitting process, had been passed only 4 years prior to the legislative authorization for the bridges and, although Section 404 permits were required by the time actual bridge construction began, they were not an important consideration when the discussions on the environmental impacts and needed mitigation began. The primary permit that the FDOT had to have at that time was from the Florida DER, which itself had just been created in 1975 by combining the former Department of Pollution Control with other related State functions. The new State environmental agency had no established regulations or procedures, and it was agreed that a single program would be developed to address the potential environmental damage from all the bridge replacements by negotiation among the agency staffs. The major players for the State of Florida were the FDOT, the DER, and the Department of Natural Resources (DNR). The involved Federal agencies were the COE, the FWS, the National Marine Fisheries Service (NMFS) (both were in the U.S. Department of the Interior at that time), and the U.S. Coast Guard.

## EARLY DESIGN PLANS AND CONFLICTS

The original intention of the transportation engineers was to replace as many of the bridges as possible with filled-in causeways, that were installed with culverts for water circulation--a technique that would have been cheaper and made repair and replacement easier after storm damage. The engineers argued highway safety, increased employment for the region, and storm evacuation benefits; there was even talk of a military evacuation involving the landing of C-130s on U.S. 1. The DER, on the hand, objected strongly to causeways, being concerned about the many restrictions to movement of ocean currents, plants, and animals between the Atlantic Ocean and the Florida Bay. It was also concerned about the project because of the potential impacts on water quality from construction and the increased slope erosion. Their preference was for bridges only, to be as closely aligned as possible with the original ones.

There were various alignment issues related to individual bridges. Alignment was complicated by the presence of the aqueduct that provides the Keys with their supply of fresh water; it was constructed beneath the old bridges and would have to be transferred to any new ones. The DNR and the FWS were concerned about loss of habitat as a result of the destruction of submerged aquatic vegetation--sea grass--and the mangroves that lined the shores of the islands. They argued for project design and construction procedures that would minimize these impacts and for compensatory plantings that would replace the lost vegetation. All the natural resources agencies were concerned about increased turbidity, both during the construction itself and as a consequence of the constructed nonvegetated and unstabilized slopes. The question of the impacts of construction turbidity on sea grass communities was argued in the scientific community and in the newspapers. The FDOT commissioned a 3-year research project at Seven-Mile Bridge that concluded that thunderstorms in the keys did "a lot more" damage to turtle grass beds than dredging operations did (*Key West Citizen*, May 27, 1982). A related issue was disposal sites for the considerable debris that would be generated by the destruction of the old bridges. In the end, there was no discussion of mitigation ratios and no formal mitigation policy to fall back on.

## CONSTRUCTION AND MITIGATION ISSUES

The agencies debated construction techniques and finally agreed that the contractors would use the box girder segmental design system (end-on construction); that is, building the bridge away from itself, which was new in the United States at that time. The segments were cast at another location and brought in on barges pushed by tugboats. The FDOT applied for permits for two design schemes: 1) the segmental and 2) the traditional one, and then used the appropriate permit after they decided on the design.) Alignment issues were resolved through negotiation. The NMFS recommended that backfilling and sea grass planting in the work channels be part of the permit conditions. This was not done. In the process of negotiating the disposal issue, the nonprofit Keys Artificial Reef Association (KARA) was born--an organization that continues today. It successfully removed 31,800 metric tons (35,000 tons) of rubble from the bridge construction areas to six permitted artificial reef sites between 1981 and 1987. The requirements for mitigation of sea grass and mangrove losses were addressed in the December 13, 1976 MOA, along with construction turbidity-control conditions. Loss of vegetation on the slopes of the approaches to the bridges was a third mitigation issue that arose and was addressed by one of the Particular Conditions of the DER permits: "All unpaved areas of the bridge approaches...shall be stabilized by vegetation or other methods approved by this Department." The COE permits included, as special conditions, a reference to the December 13 MOA and the statement that "sea grasses shall be replaced in like quantities in accordance with planting methods obtained from the FDOT experimental sea grass planting program." A procedure for DER monitoring of the construction process was established. Beginning with the bridge over Cow Key Channel, all 37 bridges were constructed between March 1978 and October 1982 (see Table 4-1).

The Interagency MOA established three conditions to satisfy the DER permit requirements for mitigation pertaining "to the loss and re-establishment of desirable wetland and submerged vegetation adversely affected by the construction process:

1. Turbidity barriers were to be placed wherever suspended sediments could affect aquatic grasses, and riprap barriers were to be constructed to prevent erosion of fill material beyond the construction area.

2. Red, white, and black mangroves were to be left standing wherever possible; natural reestablishment at the toe of the fill slope was to be encouraged and, in locations of new fill, mangrove revegetation would be accomplished by putting mats of sea grass litter within the swales created by rubble berms constructed just beyond the toe of the slopes. If, after 1 year, this operation had not been successful, then seedlings were to be planted along the intertidal slope at one seedling to every five lineal feet of shoreline.

3. The losses of submerged marine vegetation (sea grass) were to be inventoried by the FDOT, who would then attempt to restore the damaged areas or provide compensatory mitigation "to the extent possible under the advice and supervision of the DER and the Department of Natural Resources." This would be done by conducting some research on restoration techniques, which, if agreed to have been successful, would be duplicated elsewhere.

**Table 4-1: Bridges (37) Replaced in the Keys Bridge Replacement Program**

| Bridge | Length (ft) | Completion Date |
|---|---|---|
| Boca Chica Channel | 2,730 | 11/80 |
| Bow Channel | 1,340 | 80-81 |
| Channel No. 2 | 1,760 | 11/80 |
| Channel No. 5 | 4,580 | 10/82 |
| Cow Key Channel | 360 | 3/78 |
| Harris Channel | 430 | 80-81 |
| Harris Gap Channel | 140 | 80-81 |
| Indian Key | 2,460 | 7/81 |
| Kemp Channel | 1,030 | 80-81 |
| Lignum Vitae | 860 | 7/81 |
| Long Key | 12,040 | 7/81 |
| Lower Sugarloaf Channel | 1,260 | 4/80 |
| Missouri Little Duck | 840 | 6/81 |
| Niles Channel | 4,490 | 80-81 |
| North Harris Channel | 430 | 80-81 |
| North Pine | 660 | 80-81 |
| Ohio Missouri | 1,440 | 6/81 |
| Ohio Bahia Honda | 1,050 | 6/81 |
| Park Channel | 880 | 80-81 |
| Rockland Channel | 1,280 | 7/79 |
| Saddlebunch No. 2 | 660 | 4/80 |
| Saddlebunch No. 3 | 760 | 4/80 |
| Saddlebunch No. 4 | 900 | 6/80 |
| Saddlebunch No. 5 | 900 | 6/80 |
| Seven-mile | 35,830 | 10/82 |
| Shark Channel | 2,090 | 1/80 |
| Snake Creek | 230 | 7/81 |
| South Pine | 850 | 80-81 |
| Spanish Harbor | 3,380 | 80-81 |
| Tavernier Creek | 320 | 12/78 |
| Tea Table Relief | 270 | 6/80 |
| Tea Table Channel | 700 | 6/80 |
| Tom's Harbor Cut | 1,270 | 5/80 |
| Tom's Harbor | 1,460 | 5/80 |
| Torch Channel | 880 | 80-81 |
| Torch Ramrod | 720 | 80-81 |
| Whale Harbor | 720 | 12/78 |

Source:
Used with permission of Lewis Environmental Services, Inc. from
*Wetlands Mitigation Evaluation Report Florida Keys Bridge Replacement*, 1994.

## FDOT MITIGATION IMPLEMENTATION AND RESULTS

### Sea Grasses–Description

Sea grasses are underwater plants that grow in approximately 202,350 hectares (ha) (500,000 acres) of Florida's offshore waters and are abundant in the waters of the southern part of the State. Seven of the world's 52 species of marine sea grasses are found in Florida waters. Of those important in the Keys, the turtle grass (*Thalassia testudinum*) is the most dominant form, whereas shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*) appear in much smaller quantities in mixed beds or where conditions prevent dense turtle grass growth.

Sea grass provides important habitat and water quality functions. It is the nursery area for much of Florida's recreational and commercial fisheries and provides food and nursery grounds for a wide variety of Florida's fishes, crustaceans, and shellfish. Five communities of organisms inhabit and depend upon sea grass meadows: epiphytic, epibenthic, infaunal, planktonic, and nektonic organisms. Their water quality functions include the trapping of fine sediments and particles in their leaves and bottom stabilization with their roots. Sea grass produces oxygen, and its survival is a function of the available light, sediment depth, and turbulence/exposure in shallow water. The correct depth for successful sea grass plantings is at least 0.3 m (1 foot) of sediment and is mainly a function of the clarity of the local water. Declines in sea grass meadows are expected to produce concurrent declines in dependent marine species.

Although the natural resource agencies were asking the FDOT to replace the lost sea grass acreage, no one knew how to do it. The actual mitigation for sea grass losses proceeded as follows:

1. The FDOT funded a study at Craig Key between 1979 and 1981 to determine the technical feasibility of sea grass restoration to mitigate the losses from the bridge replacements (Continental Shelf Associates, 1982). Plugs, sprigs, and seedlings of turtle grass, shoal grass, and manatee grass were planted in 20 experimental plots; only 8 of these retained any of the transplanted matter after 2 years. Of the types of plantings, plugs had the best survival rate but their removal had a negative effect on the donor plots. Sponsors of the study recommended that replacement plugs be limited to shoal grass, because there were more likely to be appropriate donor plots available. The survey described in the 1994 evaluation report observed expanded communities of sea grass at the test sites, but could not relate them to the original plantings and surmised that they may have been the result of natural revegetation. Among the conclusions that were drawn from the Craig Key research was that replanting sea grasses was technically feasible although under certain conditions it could be very expensive--up to $42,500 per hectare/acre when scuba divers were used to do the plantings.

2. A supplemental MOA was signed by the FDOT and the DER on October 18, 1982, which stated the following:

   DOT had "undertaken a mitigation plan with the expressed purpose of replacing or restoring submerged marine vegetation in like amounts to that adversely impacted or destroyed by the bridge replacement construction activity."

FACTS:

- Fifty-one acres of sea grasses had been disrupted or eliminated by the project.

- The DOT had conducted an experimental sea grass planting program, February of 1979 to February of 1981, which included "the compilation of technical and economic feasibility data for further mitigation activities and methodologies."

- By an April 8, 1977, MOA between the DOT and the DNR, the DNR had agreed to provide, at the DOT's expense, technical assistance on sea grass mitigation sites and methods.

3. Other mitigation measures were agreed to as follows:

   - The DOT would pay $200,000 into the DER Pollution Recovery Fund.

   - The DER would use the money to restore or replace sea grasses affected by the Project or, where it is infeasible, to do other mitigation that would "enhance or benefit the marine and aquatic environment of the Florida Keys." This would constitute satisfaction of the DOT obligations.

4. The DOT subsequently wrote a check to the DER for $200,000 in return for the DER's responsibility for the sea grass mitigation, and funding Operation Sea Grass for $150,000.

5. The Florida Keys Sea grass Restoration Project, "Operation Sea Grass" was held in two 1-week sessions, in April 16-23 and August 13-20, 1983. Conducted by Mangrove Systems, Inc., under contract with the DER, each session was attended by approximately 25 people. Participants were trained and then actually did submerged plantings (using both snorkels and scuba equipment) of sea grass in 20 separate Keys locations, covering a total of 13.49 ha (33.33 acres). Subsequent plantings by Mangrove Systems included 5.66 ha (14.0 acres) in Sexton Cove and .08 ha (0.2 acres) in Boog Powell Marina, making a total of 19.23 planted ha (47.52 planted acres) of sea grass. In 1984, a 61.3% survival rate of the plantings was recorded.

The extent of sea grass meadows destroyed by the Keys Bridge Replacement Project has been calculated to have been 37.8 ha (93.33 acres), according to the 1994 evaluation report, (Lewis et al., 1994). The 1985 estimate of only 26.6 ha (65.8 acres) lost was expanded by the subsequent observation of substantial additional damage of 11.1 ha (27.53 acres) done by barge propellers during construction. A total of 9.95 ha (24.59 acres) of was permanently destroyed by fill associated with the bridge construction and an additional 2.32 ha (5.71 acres) were permanently eliminated by being shaded after project completion. The remaining 25.1 ha (62 acres) of sea grass meadows were torn up either by dredging 6.6 ha (16.25 acres) or by propeller cuts during construction 18.5 ha (45.71 acres), including the 11.1 ha (27.53 acres) discussed above). See Table 4-2.

### Table 4-2: Sea Grass Losses

| Cause of Losses | Acres Lost | Hectares Lost |
|---|---|---|
| Project fill | 24.59 | 10.0 |
| Project dredging | 16.25 | 6.6 |
| Shading caused by project | 5.71 | 2.3 |
| Propeller wash and cutting during construction | 45.71 | 18.5 |
| Total Losses | 92.26 | 37.4 |

### Table 4-3: Sea Grass Mitigation Efforts

| Mitigation Effort | Acres | Hectares |
|---|---|---|
| On site | | |
| Acres of lost sea grass available for on site replanting | 79.37 | 32.12 |
| Actually replanted on site | 33.34 | 13.49 |
| Survived on site, 8/1984 | 20.43 | 8.27 |
| Present on site, 9/1993 | 56.64 | 22.92 |
| Off site | | |
| Survived off site, 9/1993 | 76.55 | 30.98 |
| Total survived, 9/1993 | 133.19 | 53.90 |

## Sea Grasses–Conclusion

The sea grass plantings were not successful, but the losses were mitigated (Table 4-3). A total of 37.8 ha (93.33 acres) was destroyed, leaving 32.1 ha (79.37 acres) of that area available on site for replanting. The FDOT attempted to replace 13.49 ha (33.33 acres) of this during "Operation Sea Grass," but in 1984, it appeared that only 8.27 ha (20.43 acres) had survived. Ten years later, the replanted acreage had expanded to 22.92 ha (56.64 acres), presumably by natural revegetation. Attempts to mitigate the losses off site had resulted in another 31 ha (76.55 acres) of observable new sea grasses in 1993, most of which 25.2 ha (62.2 acres) was in the Boca Chica lagoons as a result of the tidal connection accomplished by the culvert installations. In retrospect, most of the participants in the early mitigation attempts agreed that establishing the conditions for sea grass to regenerate was more important than doing the actual plantings–where sea grass could grow, it did; where the conditions were not right, it didn't.

## Mangroves–Description

Mangrove ecosystems are among the most productive ecosystems in the Keys, with a variety of important values that stand in contrast to the perception of them as impenetrable, mosquito-infested, and unattractive (which, largely, they are). Their most important functions in the Keys are the following:

> Shoreline stabilization: the trapping, holding, and stabilizing of intertidal sediments; protecting landward habitats from hurricane damage, and mitigating the effects of storm waves.
>
> Habitat for endangered species: mangroves are important habitats to at least seven endangered species in south Florida (American crocodile, hawksbill sea turtle, Atlantic Ridley sea turtle, Florida manatee, bald eagle, American peregrine falcon, and brown pelican); five endangered subspecies (Key deer, Florida panther, Barbados yellow warbler, Atlantic salt marsh snake, and eastern indigo snake); and three threatened species (American alligator, green sea turtle, and loggerhead sea turtle).
>
> Sport and commercial fisheries: most of the commercial varieties of fish in the area utilize mangrove habitat in their life cycles, including oysters, blue crabs, spiny lobsters, pink shrimp, snook, mullet, spotted sea trout, gray and other snapper, tarpon, sheepshead, and ladyfish.

Mangroves are not a taxonomic category but, instead, are an ecological group that exhibit certain common characteristics. The features that mangroves share are their development of aboveground aerial roots: stilt or prop roots in the case of red mangroves, air roots or pneumatophores in the case of black mangroves, and lenticels in the lower trunk in white mangroves. These root systems spread horizontally over wide areas but are anchored with few underground roots and no tap root. These aerial roots collect masses of leaf detritus, attract algal communities and large populations of marine fungi, provide protection for a wide variety of invertebrates in the maze of prop roots and muddy substrates under them, and are the habitat for spiny lobster juveniles. Direct grazing insects and the mangrove tree crab feed on the leaves, prop roots, and mud algae; filter feeders live on the prop roots and filter phytoplankton and detritus from the water; mobile invertebrates skim detritus algae and small animals from the mud and forest flood surface; and carnivores feed upon all the others--the blue crab (*Callinectes sapidus*), caridean shrimp, snapping shrimp, and penaeid shrimp that take shelter and eat there. "From the economic point of view, the pink shrimp (*Penaeus duorarum*) is the most important species associated with mangrove areas (Odum et al., 1982).

The typical sequence of species in the Keys mangrove communities, moving from the water's edge upland, is red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*) and, finally, buttonwood (*Conocarpus erectus*) and upland species. All these species are present in the scrub forests that fringe the coasts of the Florida Keys. Although they differ in a number of features, they all exhibit the maze of aerial roots that trap the detritus provided by decayed leaf litter, the basic energy source for food chains, and that provide the protected habitat for juvenile fishes and invertebrates.

**Mangroves–Living Conditions**

Among the factors that control and limit the distribution of mangroves are climate, salinity, tidal fluctuation, and substrate (Odum et al., 1982). They need temperatures above 65° F, and they grow best in fine-grained muds in environments with low wave action. Although they do not require salinity, anaerobic sediments, or tidal fluctuation to survive, their ability to withstand these conditions gives them a strong competitive advantage in such environments.

**Mangroves--FDOT's Role**

The FDOT's inventory of mangrove losses showed 20.65 ha (51.03 acres) permanently lost to fill or excavation. This had to be mitigated, according to the general terms of the December 13 MOA, by 12,842 linear m (42,250 feet) of planted mangroves at the toe of the slopes of the bridge approaches by placing litter within the swales created by the berms specified in the MOA. The berms, which had been constructed by a contractor without any apparent consistency of height or distance from the shoreline, protected the mangrove seedlings and propagules from strong wave action. If they were positioned correctly and erected to the proper height, they played an important role in mangrove survival.

**Mangroves--Mitigation Plantings**

Actual plantings of mangrove propagules that were done at four locations (Bahia Honda, Spanish Harbor, the Boca Chica Bridge Causeway, and Stock Island) satisfied the mitigation MOA requirements for 5060 linear m (16,600 linear feet) of plantings. The plantings were done by inmates from the Florida State Road Prisons, under a contract between the FDOT and the Florida Department of Corrections, at the specified one propagule every 1.52 m (5 feet). It was clear, upon completion of this phase, that the FDOT did not own sufficient right-of-way in the Keys to allow them to plant the additional 8,100 m (25,650 linear) feet necessary to satisfy the terms of their agreement with the DER. They initiated a search for new sites on public land.

Road fill for the old Overseas Railroad and other development activities had cut off numerous inland lagoons on the Keys from their original access to ocean tides, resulting in increased salinity and consequent stress on associated living organisms. In their search for more sites for mangrove mitigation, FDOT personnel had identified two lagoons thus isolated as possible candidates: a 2.67-ha (6.6 acre) shallow bay-side lagoon on the west end of Bahia Honda, and a system of shallow semi-impounded interior lagoons on the Atlantic Ocean side of Boca Chica Key, roughly 3.2 by 1 km (2 miles by 0.6 miles) in area.

A 6-meter (20-foot) swale was excavated through a mangrove ridge separating Bahia Honda from the Florida Bay in early April, 1981 (Exhibit 4-6). Three monitoring surveys were conducted: one prior to the excavation (in February 1979), and two subsequent ones (in August 1981 and September 1982 (Jordan, 1986)). The surveys revealed the following results:

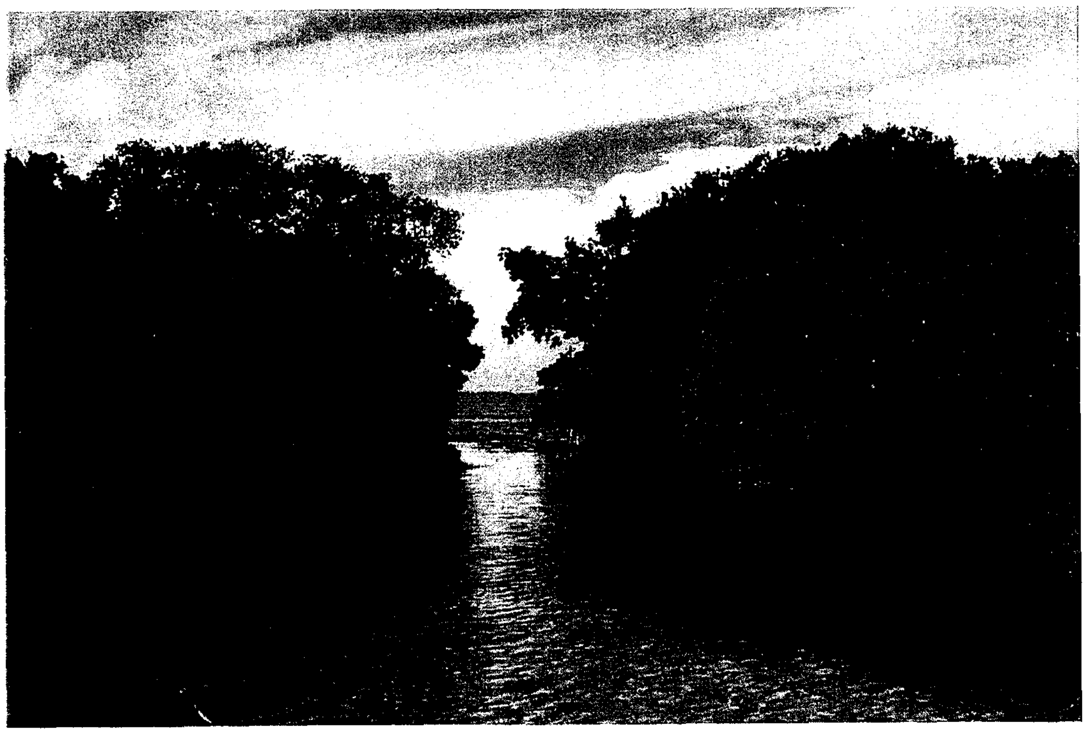
> A daily tidal regime was established that reduced the original hypersaline conditions.
>
> The blue-green algae that had dominated prior to the excavation disappeared and were replaced by *Batophora oerstedi*, an alga typical of local flushed lagoons. There were no changes in the benthic community.
>
> Mangrove growth and seed population were stimulated, particularly for black mangroves.
>
> Existing fish species increased from two to seven, and fish populations expanded by several orders of magnitude.

Ten years later (1993), a survey recorded significant colonization and growth of volunteer red mangroves and numerous fish and wildlife species including reddish egrets, roseate spoonbills, and mangrove water snakes.

Encouraged by the observations at Bahia Honda, the FDOT initiated more extensive work on U.S. Navy property on Boca Chica Key. In early 1982, they installed three sets of 4-barrel 1.06 x 0.73 meter (42 by 29-inch) aluminum culverts about 1.29 km (0.5 mile) apart under Old Boca Chica Road, connecting the south edge of the lagoons to the Atlantic Ocean (Exhibit 4-7). The culverts were designed to produce an exchange of water and biota with the Atlantic, a flushing of the lagoons, and reduction in salinity. In addition to the culvert installation, the FDOT planted 80,000 red mangrove propagules, again with the use of prison labor, near culvert C-4, completing the work in August 1983, 18 months after the culverts were installed. Photographs of control plots, taken in May 1985, showed healthy red mangrove seedlings that had developed, by 1993, into a flourishing red mangrove community (Exhibit 4-8).

The 1993 survey of the lagoons connected to the culverts discovered new areas of sea grass where none had existed previously; an extensive new colonization and growth of both red and black mangroves; and a wide variety of fish, fiddler crabs, birds, and shorebirds. Although the extension of the range of mangroves at culvert 4, where 80,000 propagules were planted, was only slightly greater than that at culverts 3 and 2, where natural revegetation occurred, the 1994 report concluded that "Although pioneering mangroves are common in the interior here, the planting of mangroves resulted in considerably larger mangrove stands and larger trees" (Lewis

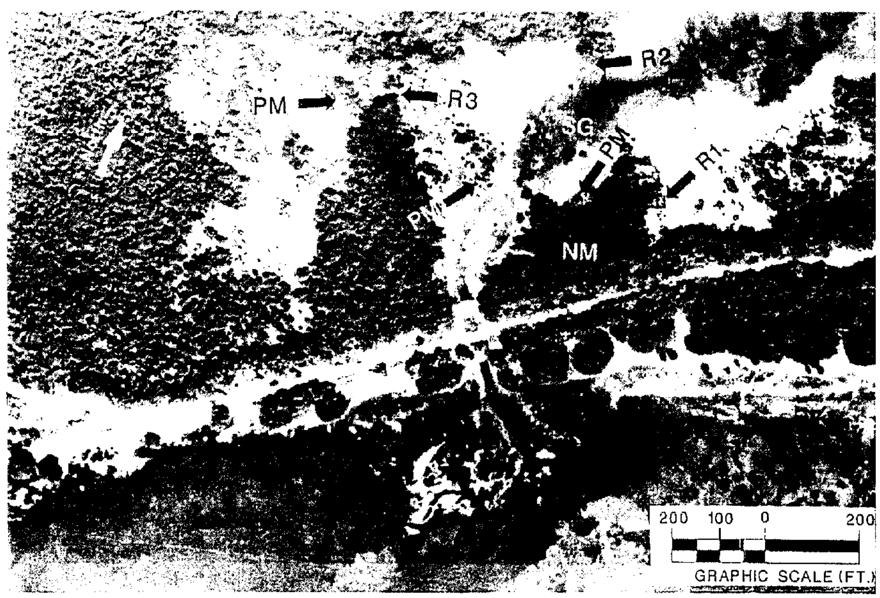
Bahia Honda Lagoon, circulation cut, 4/81.



Bahia Honda Lagoon, circulation cut, 4/81.

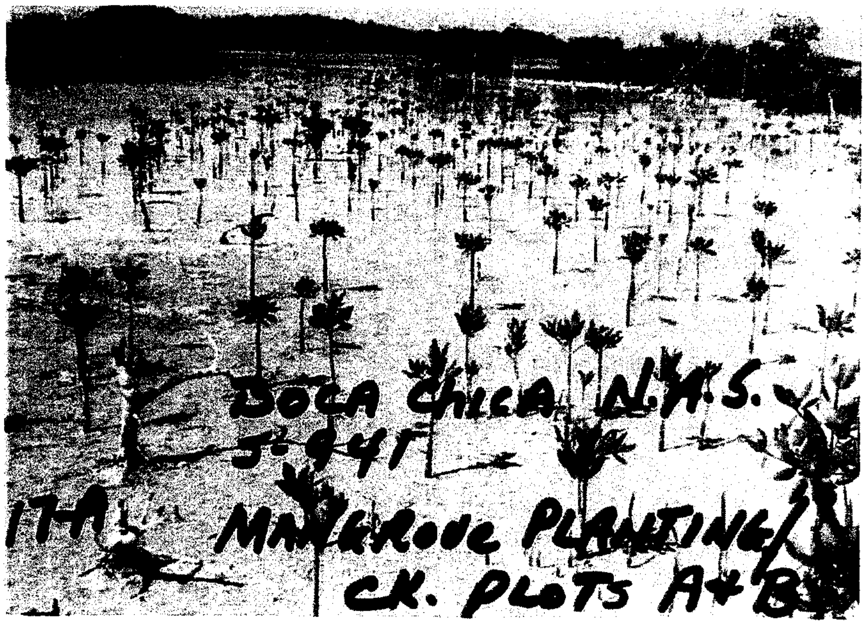
EXHIBIT 4-6: BAHIA HONDA LAGOON (USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM <u>WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994)</u>


Vertical aerial photograph taken February 25, 1981, of the south side of the Boca Chica Lagoon at the location culvert C4. Reference points R1, R2, and R3 are also shown below. Arrow indicates future location of culvert (see below).




Vertical aerial photograph of the same site, taken February 17, 1991. Reference points are the same as above. R1 indicates a square planted mangrove plot. NM indicates new volunteer mangroves mixed with additional planted mangroves (PM) and SG new volunteer seagrass.

EXHIBIT 4-7: BOCA CHICA LAGOON (USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994)




Typical planted red mangroves at culvert C-4, Boca Chica Lagoon, 1985.

Typical volunteer and planted red mangroves at culvert C-4, Boca Chica Lagoon, 1993. Staff is 2 m tall.

EXHIBIT 4-8: BOCA CHICA LAGOON (USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM <u>WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994)</u>

Lower Sugarloaf Channel, Miami Gulf side, view west, 9/97.

Lower Sugarloaf Channel, erosion limiting revegetation, Miami Gulf side, view west, 5/93.

Lower Sugarloaf Channel, Miami Gulf side, view west, 4/82.

EXHIBIT 4-10: APPROACH SLOPE REVEGETATION, LOWER SUGARLOAF CHANNEL (THE 4/82 AND 5/93 PHOTOGRAPHS USED WITH PERMISSION OF LEWIS ENVIRONMENTAL SERVICES, INC. FROM WETLANDS MITIGATION EVALUATION REPORT FLORIDA KEYS BRIDGE REPLACEMENT, 1994 AND THE 9/97 PHOTOGRAPH BY N. PHILIPPI)

et al., 1994). In total, almost 324 ha (800 acres) of mangroves had been enhanced and 13.64 ha (33.7 acres) of new mangroves had been created by the mitigation program (Table 4-4).

## Approach Slope Revegetation

The issue of stabilization of the newly constructed bridge approach slopes arose out of concern for water quality degradation by erosion of the fine silts and sands of the construction materials, particularly during rainstorms. Sodding was considered to be prohibitively expensive and, as an alternative, the FDOT used a "mower clipping" technique, spreading cut mulch and seed from other grassy areas in the Keys. The DOT conducted preliminary tests in 1981 at the Lower Sugarloaf Channel bridge that were deemed by the DER to be successful and by the DOT to be ineffective (Lewis et al, 1994). However, the FDOT began to spread bagged mowed mulch on sites required by the DER, avoiding those slopes where least terns (*Sterna antillarum*) were discovered to be nesting. They completed the procedure at 14 bridges in the Lower Keys in 1982 and 1983, covering approximately 1022 m (11,000) linear feet of new bridge approach slopes. The remaining bridges were exempted from treatment by the DER either because they were vegetating naturally or were being used for nesting by least terns. An example is depicted in the three photos of the Lower Sugarloaf Channel bridge approach slope (Exhibit 4-10). The DER found the approach to be satisfactory and signed off on the DOT's slope revegetation efforts on July 15, 1983.

### Table 4-4: Mitigation of Mangrove Losses

| Locations of Mangrove Revegetation | Acres/Ha Lost | New Acres/HA | Acres/HA Restored |
|---|---|---|---|
| Bridge approach slopes | 51.03/20.6 | 14.50/5.9 | 0 |
| Bahia Honda | 0 | 1.35/.55 | 0 |
| Boca Chica culvert 2 | 0 | 6.45/2.6 | 0 |
| Boca Chica culvert 3 | 0 | 4.58/1.85 | 0 |
| Boca Chica culvert 4 | 0 | 6.49/2.62 | 0 |
| Boca Chica Lagoon | 0 | 0 | 800/323 |
| Total | 51.03/20.6 | 33.37/13.5 | 800/323 |

HA = Hectares

## CONCLUSIONS

The ecological environments of the Florida Keys, with all their variety and complexity, are related in ways that are only partially understood. The importance of the known impacts of the Keys Bridge Replacement Project on these environments--the restriction of flows from the Florida Bay to the Atlantic Ocean; the increased turbidity resulting from the construction activities, the loss of sea grass and mangrove communities and the denuding of bridge approach slopes; and the reduction of sea grass and mangrove habitat--are appreciated in the general sense without being totally understood in their specifics. The ultimate impact of the bridge replacement project is as undefinable today, therefore, as it was in the late 1970s when it was begun. In the short term, if 10 years can be considered short, the restoration of mangrove and sea grass communities to compensate for losses resulting from the Keys bridge replacement project was very successful. Not only were the lost ecological assets replaced in the general vicinity of the project, but the concerns of the natural resources agencies were satisfied.

Some conclusions can be drawn that are related to that success:

1. The discussions initiated by the permit requirements resulted in avoidance and minimization of certain impacts that otherwise might have occurred: 1) the bridges were replaced by other bridges rather than by filled causeways; 2) bridge alignments were negotiated on a bridge-by-bridge basis to reduce specific impacts; 3) appropriate spoil disposal sites were secured, and construction procedures were adopted that would minimize erosion.

2. On-site, in-kind compensation restoration activities were largely unsuccessful:

   a) There was a net loss in turtle sea grass beds. The sea grass planting had a low survival rate and, where survival was observed, it was impossible to tell how much could be attributed to natural revegetation.

   b) There was a net loss in shoreline mangroves because there was insufficient land available. Because original inventories recorded quantity but not quality, the relative values of the before and after mangrove communities cannot be assessed.

   c) Bridge approach slope revegetation was successful quantitatively; again, the qualitative success is unknown because preconstruction inventories were not taken.

3. Off-site compensatory restoration was extremely successful: when tidal circulation was reestablished at the Bahia Honda and Boca Chica interior lagoons, mangrove and sea grass communities were expanded well beyond the losses that resulted from the project, and attendant biotic communities expanded and flourished as well.

At least three functions were perceived as being affected by the project at its beginning: water flow through and between the islands; caused by causeways; wildlife habitat by destruction of the fringe mangrove and sea grass meadows adjacent to the affected bridge sites; and water quality by destruction of the mangrove and sea grass communities, as well as by the loss of slope vegetation and construction activity. Eliminating causeways from project design largely preserved the water movement functions. Habitat was definitely expanded in the Boca Chica lagoons where, if properly maintained, it can only be expected to improve. If offshore water quality has suffered as a result of the project, although there is no objective way of assessing whether it has, it would be an important impact that was not mitigated.

Without the creativity and perseverance of some of FDOT personnel in accomplishing the interior lagoon flushing, the mitigation would have been a failure in every sense. Without any permitting process, the potential for environmental damage would have been substantially greater--the careful discussions among agency staffs resulted in compromises on both sides that might not have been accomplished even 10 years earlier.

## ACKNOWLEDGMENTS

The Environmental Management Office of the FDOT was extremely helpful, and Gary Evink in particular. Gary was the FDOT's State ecologist during the project, and today, as Head of the Environmental Management Office, he initiated and funded the important 1994 evaluation report. Charles Allen, who was the FDOT permit administrator during the Bridge Replacement Program, and Dave Zeigler, who supervised all the mangrove and slope planting operations and participated in Operation Sea grass, were able to reconstruct large parts of the earliest period. Another valuable source of information was Roy (Robin) Lewis who, as founder of Mangrove Systems, was a principal in the Craig Key sea grass research and conducted Operation Sea grass and, as Lewis Environmental Services, did the 1994 evaluation report. Pat McNeese, of the Lewis Environmental Services office on Sutherland Key, enthusiastically tracked down all the old mitigation sites. Other important sources that took the time to stir up 20-year-old memories and dig into files were R. J. Helbling of the Marathon office of the Florida Department of Environmental Protection and a biologist for the Florida Department of Pollution Control in 1975; Hanes Johnson, now with the EPA's Wetlands Section in Atlanta and a marine biologist for the DNR at the time of the project; Joseph Carroll, of Carroll and Associates in Vero Beach and a field supervisor with the U.S. Fish and Wildlife Service (FWS) in Vero Beach when the project was underway; Shirley Stokes with the COE; Eric Hughes, with EPA in Jacksonville; and Mark Thompson, with National Marine Fisheries now, and a biologist at EPA at the time of the project. Kalani Cairns, a current FWS Biologist at Vero Beach, took the time and trouble to unearth old documents.

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# CHAPTER 5

## YAHARA RIVER MARSH

What was once rolling prairies, capped by forests of oak and hickory and interspersed in the drainage ways and low-lying landscapes with wet prairies, sedge meadows, and marshes, has been transformed over the past 150 years into a vibrant urban center in south-central Wisconsin (Exhibit 5-1). In the 1850s, the natural landscape gave way to agricultural production and was replaced by the tilled field and grazed pasture. The upland prairies and forests were converted first, and the more-difficult-to-farm wetlands were converted last, if at all. Even after complete settlement of the region, many wetlands remained. Typically, these recalcitrant landscapes survived along the drainage courses and around the numerous lakes in the area. But even these gave way to the development in and around Madison, Wisconsin's capital city, following World War II.

As development progressed, traffic congestion became an issue of great public concern. In the early 1960s, traffic congestion and accident rates were rapidly escalating along U.S. 12, the transportation corridor traversing the southern edge of Madison (Exhibit 5-2). Through this corridor flowed traffic from I-90 and 94 and U.S. 18 and 51 on the eastern edge of the city; from U.S. 14, 18, and 151 on the southern edge; and from U.S. 12 and 14 on the western edge. The congestion grew worse through the 1970s and 1980s as Madison and the surrounding communities expanded (Exhibit 5-2). By the 1980s, traffic volumes far exceeded the design capacity of the existing corridor.

Engineers with the Wisconsin Department of Transportation (WDOT) grouped the solutions to the traffic problems into two alternatives: expansion and improvement of U.S. 12/18 or construction of a limited access highway on a new alignment (referred to as Madison South Beltline) over the Yahara River and through the surrounding marsh. The WDOT and the Wisconsin Department of Natural Resources (WDNR) debated the environmental impacts and how they should be mitigated. The Wisconsin Wetlands Association was established to preserve the integrity of the Yahara River and the surrounding marshlands, often referred to as the Upper Mud Lake Wetland, but for this publication called the Yahara River Marsh.

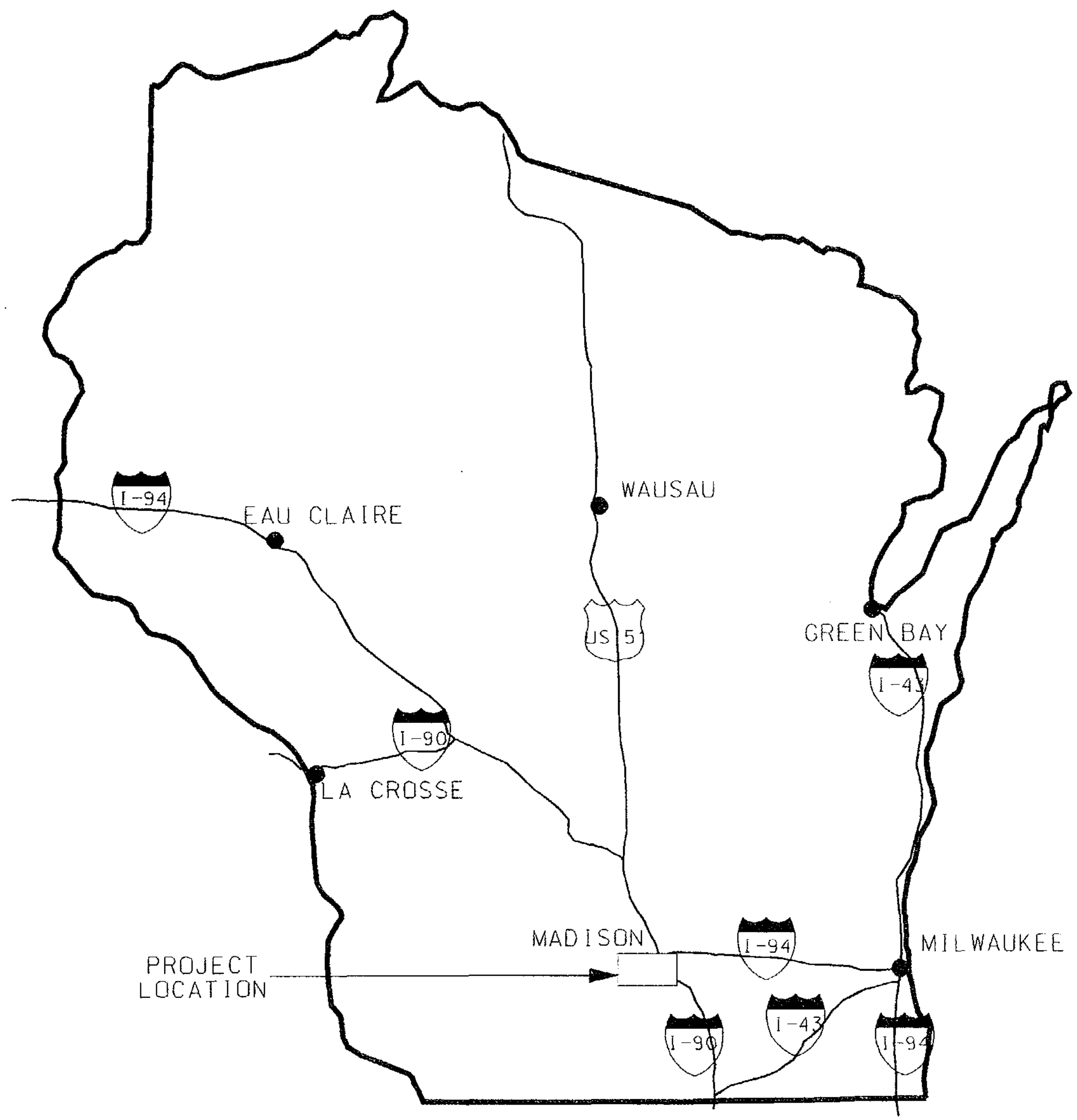



EXHIBIT 5-1: PROJECT LOCATION

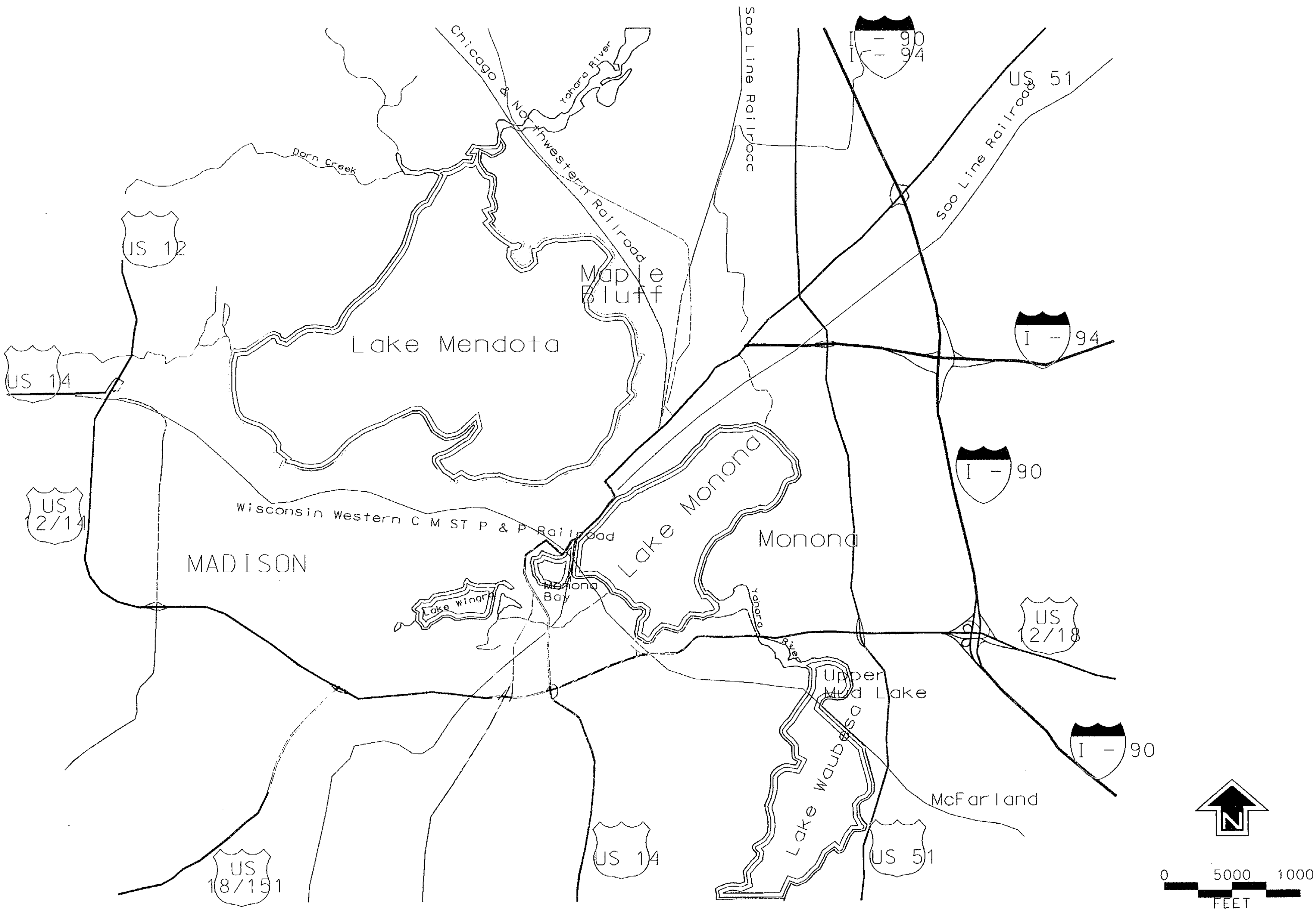


EXHIBIT 5-2: METRO-MADISON

## ENVIRONMENTAL AND SOCIAL SETTINGS OF PROJECT AREA

Located in south-central Wisconsin, the highway project falls within the temperate zone of the continental United States. The climate is moderately warm and humid. Approximately 81.3 centimeters (cm) (32 inches) of precipitation falls annually. Of this amount, 35.6 cm (14 inches), or 44 percent, occurs as snow or sleet. The wettest month is July and the driest month is December. The annual mean minimum temperature is -18°F and the maximum is 95°F. The mean temperature is 48°F. Summer months are characteristically warm, with August--the hottest month of the year--having a mean monthly temperature of 70°F. The coldest month is January, averaging 10°F. Given different seasonal distributions, not all of the precipitation falling on the region is returned to the atmosphere by evapotranspiration. Of the 81.3 cm (32 inches) of precipitation, approximately 16.8 cm (6.6 inches), or 21 percent, leaves the region as streamflow.

Dane County was settled in the 1840s. Madison was incorporated in 1862 and became the capital of Wisconsin in that same year (Durrie, 1874). After World War II, Madison began to expand rapidly and, at the same time, smaller satellite communities began to develop. The population of Dane County, the county in which Madison and the project are located, grew from 131,000 people in 1940 to 290,000 in 1970. The population density increased from 42 persons per square kilometer (km) to 93 (109 persons per square mile to 241 (Exhibit 5-4)). Today, 393,000 people live in Dane County, resulting in a density of 126 persons per square kilometer (327 persons per square mile). The predominant land use is agricultural, representing 80 percent of the 311,214 hectares (ha) (769,000 acres) of land in the county.

With the arrival of European settlers, numerous plans were developed for the utilization of the Yahara River and its water resources. Navigation and hydropower were early interests, but throughout the public discussions of the plans, the recreational potential of the river and interconnected four lakes was not lost on the public or their political leaders. Several of the early proposals suggested development of resorts on the banks of the lakes. Today, the University of Wisconsin's Madison campus occupies the southern shoreline of Lake Mendota (also referred to as Fourth Lake). All four lakes (Mendota, Monona, Waubesa, and Kegonsa) were altered to one degree or another over the years. Each has a hydrologic control structure at its outlet and they are surrounded by development, receive runoff from highly urbanized watersheds, and are crossed by railroads and highways. Still, the lakes and their remaining wetland fringes offer high quality recreational opportunities and, as such, provide great benefits to the residents and visitors of the metropolitan area. The proposed road would cross the Yahara River between the outlet of Lake Monona and the upper reaches of Lake Waubesa.

## Yahara River Watershed

The Yahara River conveys the vast majority of streamflow to and from the project area. After climate, the river is the most significant defining force of the affected riparian marshes. The depth, frequency, and duration of surface inundation of the marshes are a function of the river's stage. The river's stage also affects groundwater elevations and the rate and quantity of water moving into and out of groundwater storage. The nutrient balance is inextricably tied to the river and the underlying soils. In turn, the hydrologic and water quality characteristics of the river are defined by the biological, geochemical, topographic, and land use characteristics of its watershed.

The Yahara River rises on the northern edge of Dane County. It flows north into Columbia County for a short distance and then turns south approximately 29 km (18 miles) from the project. The river generally flows from north to south-southeast. It is a tributary of the Rock River, joining this stream, near Indian Ford, Wisconsin, about 40 km (25 miles) southeast of the project. Its watershed, upstream of the project, is shaped somewhat like a light bulb, narrowing between two glacial ridges as it passes through Madison and the project site. The north-south axis of the watershed is 35.4 km (22 miles) and the east-west axis is 27.4 km (17 miles). The elevation of the upstream watershed boundary is 320 meters (m) (1,050 feet) above mean sea level (msl); the junction with the Rock River is 238 m (780 feet) msl. The mean slope of the river is 0.0023.

In total, the Yahara River watershed encompasses more than 1,295 square km (500 square miles), of which 958 square km (370 square miles) are tributary to the project. The topography of the watershed is characterized by glacial features and deposits. Approximately 16 km (10 miles) west of the project site is Mount Horeb, the highest elevation in Dane County, 274 m (900 feet) above msl. The glacial drift is approximately 24.2 m (80 feet) in depth, made up of clays, silts, sands, and gravel. The surface soils vary from one landscape position to another. On steeper slopes, Dodge and St. Charles soils are found, whereas Otter and Orion soils are present in the lower-lying areas in and along the drainage ways.

Based on 65 years of data (U.S. Geological Survey, 1997), at McFarland, Wisconsin, 3.2 km (2 miles) downstream of the project, the yield of the Yahara River is 16.8 cm (6.62 inches) and the mean annual daily flow is 4.5 cubic m per second (cms) (159 cubic feet per second (cfs)). The highest recorded annual mean is 9.5 cms (336 cfs) and the lowest is 1.8 cms (63.8 cfs). This low variation in flow, despite extensive urbanization in the lower portions of the watershed, is due in large part to extensive wetlands in the watershed and to numerous lakes, particularly those in the Madison metropolitan area, Mendota, Monona, Waubesa, and Kegonsa. The stage of the river through the project corridor is controlled by a dam on the outlet of Lake Waubesa, where the U.S. Geological Survey's gauge is located. A structure on the outlet of Lake Mendota controls flows entering the project area, attenuating flows moving downstream. During the late spring and summer, the normal water level between Lakes Waubesa and Monona, bracketing the project, is maintained at 259.0 m (849.6 ft) msl.

Because the project is only a short distance upstream of the dam, and the intervening topography is very flat, water elevations throughout the project area reflect those at the dam, with only minor variations. The broad, low-lying flood plain through the project area accommodates considerable flood storage; consequently, flooding in this reach of the river is not an issue. Given the geomorphic and hydrologic conditions of the site, it is ideally suited for wetlands, and wetlands existed here for some time before settlement.

The water quality of the Yahara River is considered to be good (FHWA, 1984). The dissolved oxygen remains high (10 to 12 parts per million (ppm)) throughout the stream system, and the nitrogen ($NO_3$) concentrations are low to moderate (0.21 to 2.8 ppm), as are phosphorus ($PO_4$) and suspended solids concentrations (0.04 to 0.12 and 2.9 to 28 ppm, respectively). Still, the waters are considered eutrophic. The abundance of rooted aquatic vegetation (macrophytes) and frequent algal blooms validate this conclusion. Despite the urbanization in the lower portion of the Yahara River and the agricultural activities in the upper portion of the river, the quality of the river is remarkably similar in both reaches. Credit for the good water quality in the river might be given to the abundance of wetlands and lakes distributed throughout the watershed.

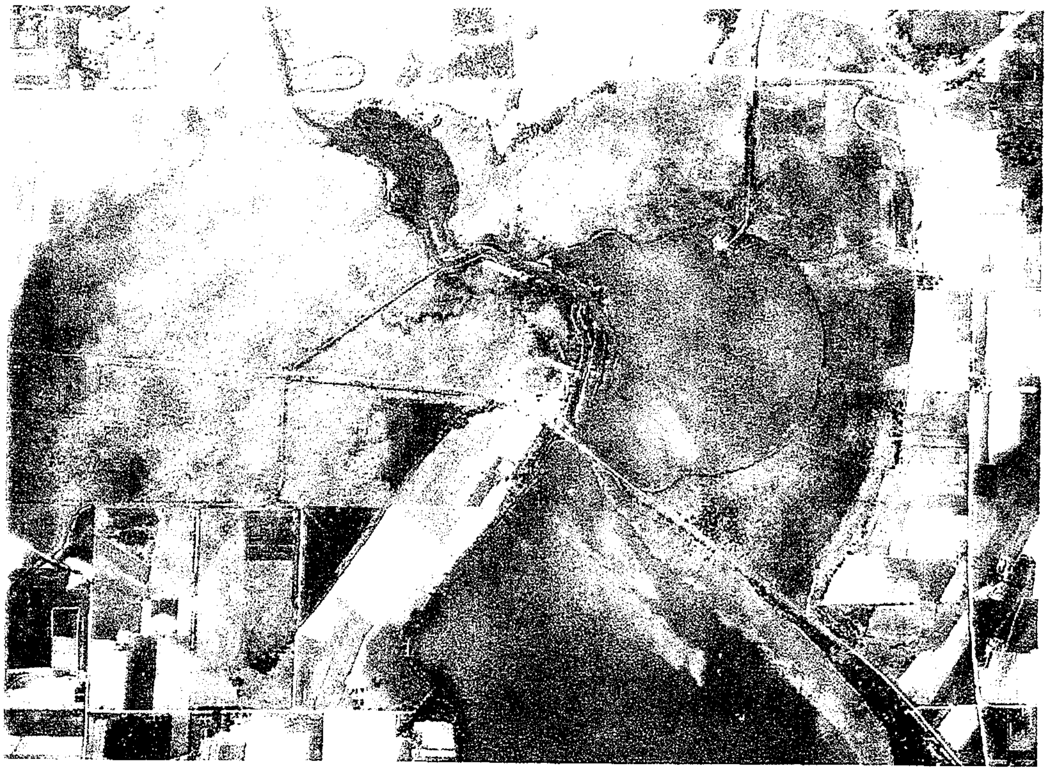
Owing to the flat, natural stream gradient and the dams, the current velocities of the Yahara River are very slow. This minimizes bank erosion and channel scouring, which, in turn, minimizes turbidity. The clear water promotes the propagation of submerged and emergent vegetation. Combined, the slow-moving water and ample plant growth afford substantial water quality benefits.

Groundwater movement in the large wetland complex west of the river is from the northwest to the southeast. In the western upland fringe, the groundwater occurs at 0.30 to 7.6 m (13 to 25 feet) below the soil surface. As the surface elevation falls, the differential becomes less. Hydric soils, such as Houghton, begin to dominate and the hydraulic gradient flattens on the approach to the river. In the low-lying areas adjacent to the river, the groundwater regime is very stable, saturating surface soils. Groundwater quality is considered good.

## Natural Vegetation

Curtis (1959) divided Wisconsin into two floristic provinces by a line running from southeast to northwest, just north of Dane County and the project area. In the southern province, he identified seven plant communities: mesic, xeric, and lowland forests, prairie, oak savanna, pine barrens, and sedge meadow. Except for pine barrens, each of these communities was present in Dane County prior to European settlement. The forests and prairies were the first plant communities to be altered by settlement. They served to provide building materials and to cultivate agricultural crops. The low-lying areas survived longer because of their saturated soil and the extent of the engineering works necessary to drain them. Some of the sedge meadows bordering the Yahara River and present on the project site endured despite the changes in the upland landscapes and river system (Exhibit 5-3). Curtis (1959) provides a very clear description of the sedge meadow community:

> The sedge meadow is here understood to be an open community of wet soils, where more than half the dominance is contributed by sedges rather than grasses. As such, it is closely related on soils of similar moisture to fens, bogs, and wet prairies, among other open groups, and to the shrub thickets and wet forests of the closed communities. Under wetter conditions, it grades to cattail and reed marshes or other emergent aquatic groups. It usually occupies a very low position in the regional soil Catenas. The ground [surface] may be flooded in the spring or after heavy summer rains but it typically lies just above the permanent water table. The soil is either a raw sedge peat or a muck produced by decomposition of such peat, and is frequently incorporated with mineral matter deposited by overwash from the surrounding uplands. Water is always plentifully present and never a limiting factor by its lack. Excess water, however, may induce difficult conditions for many plants because of



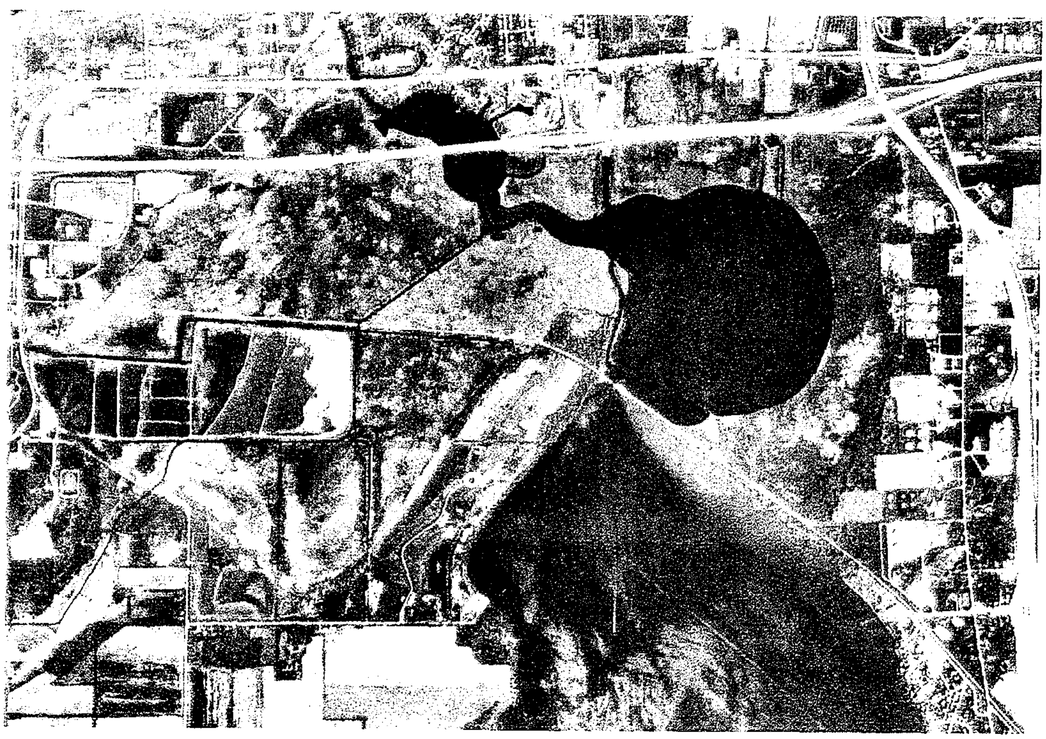


EXHIBIT 5-3: YAHARA RIVER MARSH IN 1937 AND AFTER CONTRUCTION OF SOUTH MADISON BELTLINE IN 1993

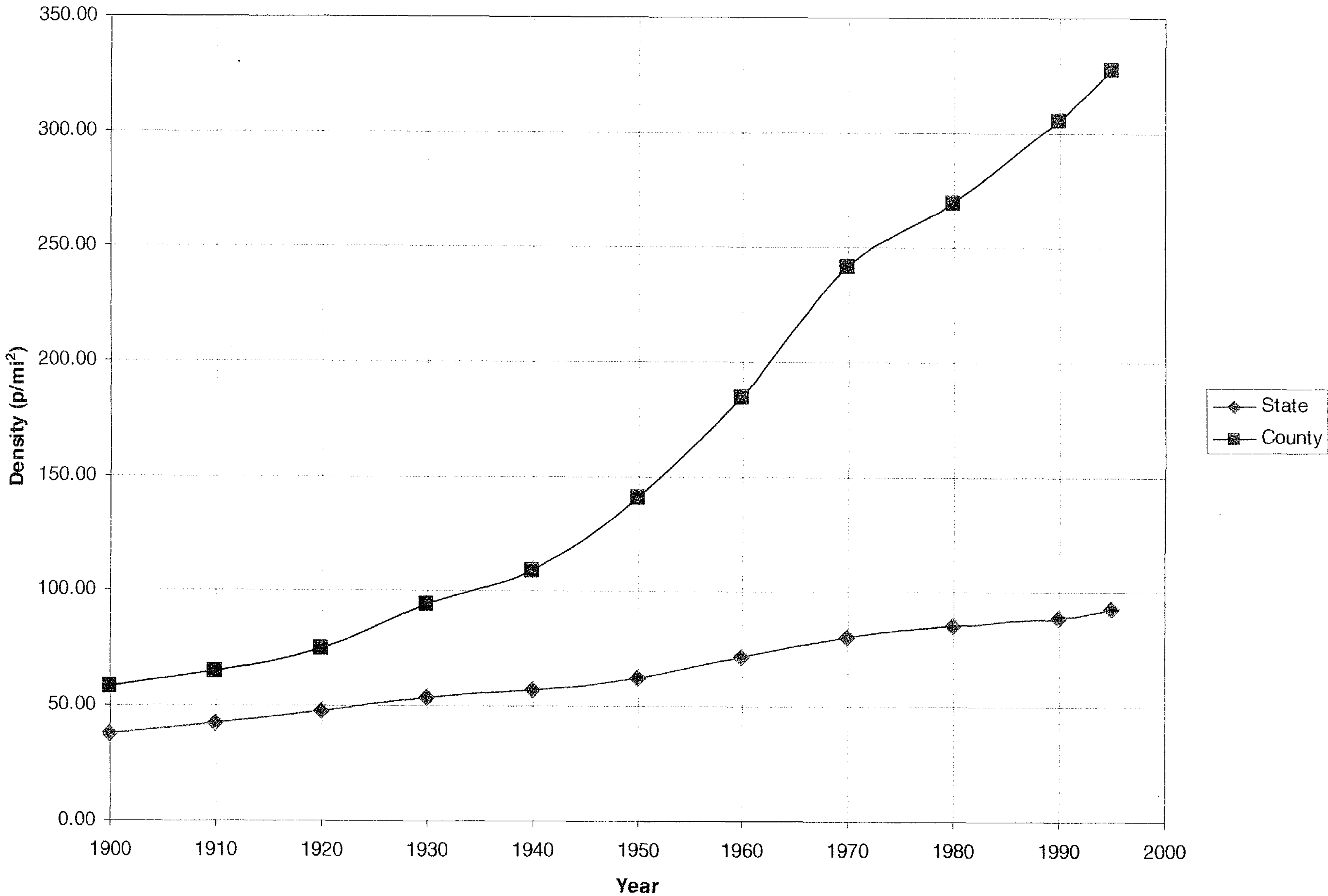



EXHIBIT 5-4: POPULATION DENSITIES OF DANE COUNTY AND WISCONSIN

> the disturbed oxygen relationships. The sedge meadow soils are frequently in a reducing condition and may reach extreme conditions in this respect, with abduction of methane or other highly reduced "marsh grasses."

This is one of the principal communities that the WDOT intended to restore and create as mitigation for losses along the new Madison South Beltline right-of-way.

### Wildlife

A good variety of wildlife uses the marshes along the Yahara River today. Regardless of the disturbance by past and present human activities, numerous species of mammals, birds, reptiles, amphibians, fish, and macro invertebrates have populated these landscapes in the past. The COE compiled a list of potential wildlife (FHWA, 1984), which included 19 species of mammals ranging from white-tailed deer to meadow vole, 84 species of birds including the pied-billed grebe, wood duck, barred owl, and red-shouldered hawk. The listed 36 species of reptiles, amphibians, and fish included the central newt, green frog, and carp. These lists were simply a tabulation of potential species. Several wildlife surveys that were conducted during the design phase of the project showed that many of the species were present.

## WETLAND CONCERNS AND MITIGATION

The WDOT responded to concerns regarding wetlands. The following paraphrases the Department's positions on a point by point basis (FHWA, 1984):

> The Metropolitan Madison E-way is a concept proposing a linear system of natural and manmade features. The framework of the concept consists of a series of public streets, walkways, railroad corridors, and other open spaces connecting many of the area's more prominent educational and environmental features. The proposed E-way lies within the jurisdictions of Dane County, the cities of Madison, Monona, and Fitchburg, and the town of Blooming Grove. Only the city of Madison has officially adopted the concept. The South Madison Beltline, which is a part of the area wide regional transportation plan for Dane County, passes through the conservancy area and along the northern edge of the proposed E-way. The city of Monona's Comprehensive Outdoor Recreation Plan states that the area zoned as conservancy may be developed, consistent with that zoning after the WDOT has acquired highway right-of-way for the South Madison Beltline.
>
> Although the preferred alternative causes 8.9 ha (22 acres) of wetland to be lost, 8.1 ha (20 acres) of wetland will be re-created, 2.0 ha (5 acres) enhanced, and the WDNR will be given ownership of these lands along with an additional 39.3 ha (97 acres) of wetlands currently owned by the WDOT, for a total of 49.4 ha (122 acres). Thus, short-term losses are considered offset by long-term gains in diversity, productivity, and protection of the adjacent wetlands.
>
> Coordination with the WDNR and the FWS on possible endangered species impacts has been completed. The results of these reviews covering two federally and two State-listed species follows:

American Peregrine Falcon--The records of the WDNR indicate that the last breeding adult was seen in Wisconsin in 1964. Further, scientists with the FWS concluded that neither alternative would have an effect on the critical habitat of this species.

Kirtland's Warbler–Although Dane County is within the migration range of the species, the WDNR records do not include any sightings in Wisconsin.

Common Tern--This species is listed as endangered in Wisconsin. The WDNR reported in 1981 that there were only two colonies left, both in Ashland Harbor on Lake Superior. Although more than 100 pairs nested in lower Green Bay in 1979, there were no nestings in 1980 in the waters of Lake Michigan. Based on this information, the apparent single sighting of this species by the consultant who conducted the waterfowl inventory could have been due to misidentification or an uncommon occurrence of the species during migration.

Blanding's Turtle–This species was included as a potential wetland habitant based on the COE's *Bio-resources Inventory for Wisconsin*. Because the species is listed as occurring in Dane County, the WDNR was contacted to confirm actual locations relative to the South Beltline corridor. The Department was informed that the nearest sightings were in the wetland south of Lake Waubesa and further that the wetland adjacent to the Yahara River Widespread [the area through which the proposed road was to traverse] is unlikely habitat due to the vegetation and moisture conditions.

Also included in the discussions were species listed in Wisconsin's Watch Category--the great blue heron, black duck, marsh hawk, and common flicker have been confirmed as inhabitants of the Yahara River Widespread, Upper Mud Lake, and their adjacent wetlands. Any significant continued loss of habitat for these species could result in a change in their status from watch to "threatened or endangered." The bullfrog was included as a potential wetland inhabitant according to the COE's computer inventory. However, there have been no actual sightings in the wetland.

The WDOT concluded that relocating the Madison South Beltline across the marsh would not significantly affect land of publicly owned parks, recreation areas, or wildlife and waterfowl refuges.

## ENVIRONMENTAL IMPACT STATEMENT

To address environmental concerns, the WDOT studied numerous alternatives, including those proposed by project opponents. Two principle alternatives survived (FHWA, 1984). Despite the greater wetland impacts, the new alignment alternative became the recommended project. The reasons were numerous: greater safety; the displacement of fewer homes and business; less economic loss during construction to the businesses along the existing alignment; reduced noise impacts; and fewer conflicts with parks, boat landings, and archeological sites. The most telling reason, however, was the shift in public support for the new alignment. At the public hearing on the draft environmental impact statement (EIS) (FHWA, 1983), 60 percent of the individuals who testified favored the new alignment; only 12 percent favored improving the old one.

This shift in public opinion may have resulted from the last minute endorsement by the WDNR of a modified new alignment. Following the hearing on the draft EIS, the WDOT, working closely with the WDNR, the FWS, and the COE, reduced wetland losses from 12.5 to 8.9 ha (31 to 22 acres). This reduction was achieved by using diamond rather than cloverleaf interchanges, adjusting the highway alignment, reducing median widths, and increasing the length of the bridge over the Yahara River, while reducing the width (FHWA, 1984).

The WDOT also proposed to mitigate wetland losses. Wetlands were to be created or restored in greater value and area than those being destroyed. The mitigation proposal included construction of sediment ponds to intercept highway runoff before reaching extant wetlands; removal of historic fill and restoration of the underlying wetlands on the DOT's property; acquisition and restoration of selected, disturbed wetlands; acquisition of additional wetlands; construction of open water areas for waterfowl habitat; and preservation, in perpetuity, of all acquired and restored wetlands.

The end result was to be 8.9 ha (22 acres) of wetlands converted to highway use, 8.1 ha (20 acres) of wetlands created, 2.0 ha (5 acres) enhanced, and 49.4 ha (122 acres) protected in perpetuity. These numbers and conditions convinced the WDNR to endorse the project. Although the agency had opposed the project for a number of years, when an agreement was finally reached between the WDOT and WDNR, they worked together to accomplish the mitigation objectives. The WDOT sought outside assistance in designing the mitigation effort, and it maintained close control over the construction and subsequent monitoring and management of the restored landscapes

The WDOT's engineers were able to modify the design of the project without requiring exceptions to standards for safety or capacity. The roadway was shifted south to avoid wetlands; bridges, rather than embankments, were used to traverse wetland areas. Wetland losses were reduced from 29.1 ha (72 acres), related to the highway design of 1972, to 12.5 ha (31 acres) at the time of the draft EIS (FHWA, 1983), and finally, to 8.9 ha (22 acres) through the environmental review and analysis process involving the WDNR, the Public Intervener, the Wisconsin Wetlands Association, and others. In the final analysis, the resource agencies and public advocacy organizations had a pronounced effect on the design of the project and on the nature of the environmental mitigation.

## RECOMMENDATIONS

Many of the objections to the original project design were well reasoned and constructive. After listing the reasons why the road should not be built through the Yahara River Marshes, the Wisconsin Wetlands Association made the following recommendations to the COE (Roherty, 1985):

> The DOT should budget adequate funds for the staff and resources for the planning and design of the restoration and enhancement projects. University, State agency, and private sector professionals in the environmental protection field should be consulted.
>
> The DOT should select construction methods that minimize disturbance of the area. Particular attention to erosion control and approach routes for heavy machinery is needed. Again outside professionals should be consulted for innovations in these areas.
>
> Funds allocated for mitigation should be used for that purpose at the site. The purchase of wetlands elsewhere is not an acceptable alternative.
>
> Field work for restoration and enhancement should be opened up for bidding separately from the bidding for road construction. While the road construction firm could perform the earthmoving work involving heavy machinery, the smaller scale work, such as planting, should be done by someone with appropriate training under the supervision of wetland scientists.
>
> The DOT should budget adequate funds for the planning and implementation of long-term monitoring to determine if the objectives of the restoration and enhancement projects are met.
>
> The entire process and its end product should be put on public display to educate the public so that others can learn from it. Once the project is completed, an interpretive center should be located on site explaining the principles, and the difficulties, of wetland restoration.

On May 8, 1984, the FHWA approved the final EIS for the Madison South Beltline. The WDOT submitted a Section 404 permit application to the COE on December 6, 1984. By today's standards, the application was quite sparse: no detailed grading, planting, erosion control, management, or monitoring plans were attached. The COE issued the public notice on this permit submittal on December 20, 1984. The Section 404 application was approved and permit number 85-136-02 issued on March 8, 1985, granting permission to "discharge approximately 207,616 cubic m (271,550 cubic yards) of granular material and rock riprap in approximately 8.9 ha (22 acres) of wetlands and waterway to facilitate the construction of the South Madison Beltline highway in conjunction with the installation of a 792-m (2,600-foot) long bridge and a 3.0 m x 2.43 m (10-foot wide by 8-foot) high box culvert."

In the conditions attached to the permit, no mention was made of the recommendations by the Wisconsin Wetlands Association. The WDOT, however, chose to act on most of the suggestions even though they were not mandated to do so. The Department retained a wide range of experts to develop a detailed plan, set goals and objectives, oversee construction, and manage and monitor the finished landscape. In fact, the only recommendation from the Wisconsin Wetlands Association that the WDOT did not implement was the suggestion that separate contractors be used for earthmoving and planting. Employees of the WDOT now indicate that planting might have been more successful if these contracts had been separated.

Construction on the highway began in the summer of 1985; wetland mitigation began in the early fall of that year. The highway and wetland mitigation were completed in the fall of 1986. Three years of monitoring followed, although not required by the COE.

## THE PROJECT AND ITS WETLAND IMPACTS

Based on traffic congestion and the incidence of traffic accidents, the WDOT proposed a new, six-lane, limited-access roadway to connect I-90 and I-94 on the east side of Madison with U.S. 12 on the west. Between these two highway corridors, a new limited access route would pick up the all-important U.S. 151 which traversed the Madison metropolitan area from southwest to northeast, as well as intercepting a number of other Federal highways and major local roads. Traffic use along the existing east-west corridor had grown from 5,000 trips per day to 50,000 trips per day between the period when planning was first begun on the corridor in 1962 until the EIS was accepted in 1985.

The wetlands on the site were mainly deep and shallow marsh. The quality of these wetlands was not particularly high, but they were a part of a much larger complex of wetlands associated with the Yahara River and the adjoining lakes. They were valued for their wildlife habitat as well as for their plant community structure. Water quality was of some concern, but did not play a central role in the arguments for avoidance. Flood control was not an issue.

The project is within Dane County, traversing three municipal jurisdictions: the cities of Madison and Monona, and the town of Blooming Grove (Exhibit 5-5). The six-lane freeway starts at John Nolen Drive on the west and extends to U.S. Highway 51 on the east, traversing 8.32 ha (3.22 miles). To reduce wetland impacts, the median strip was designed to be 7.29 m (24 feet) wide, as opposed to 20.1 m (66 feet) as originally proposed. Excluding intersections, the pavement is approximately 15.2 m (50 feet) wide in each direction and the typical right-of-way is 76 m (250 feet). In all, four intersections connect the freeway with other major highways and roads. The right-of-way required 49 ha (121 acres) of land. The bridge design called for a 792-m (2,600-foot) span–282 m (925 feet) to cross the Yahara River and 510 m (1,675 feet) to cross the associated marshes. Still, the area under the bridge deck was considered to be fill and was mitigated. Some 379,000 cubic m (500,000 cubic yards) of marsh soil (peat and muck) had to be removed to construct the road embankment. These materials, and others, were replaced by 1,140,000 cubic m (1,500,000 cubic yards) of borrow. Excavated marsh soil was stockpiled and used to spread in wetland mitigation areas.

The corridor along which the project was constructed varies in elevation from 262.1 m (860 feet) msl on the east to 275.8 m (905 feet) msl on the west. The low point is the Yahara River, with a normal water level of 257.6 m (845 feet) msl. From east to west, the corridor dips toward the river, then gradually rises in the direction of Raywood Road. Passing over the western ridge, the corridor falls in the direction of John Nolen Road. Most of the affected wetlands are found in the

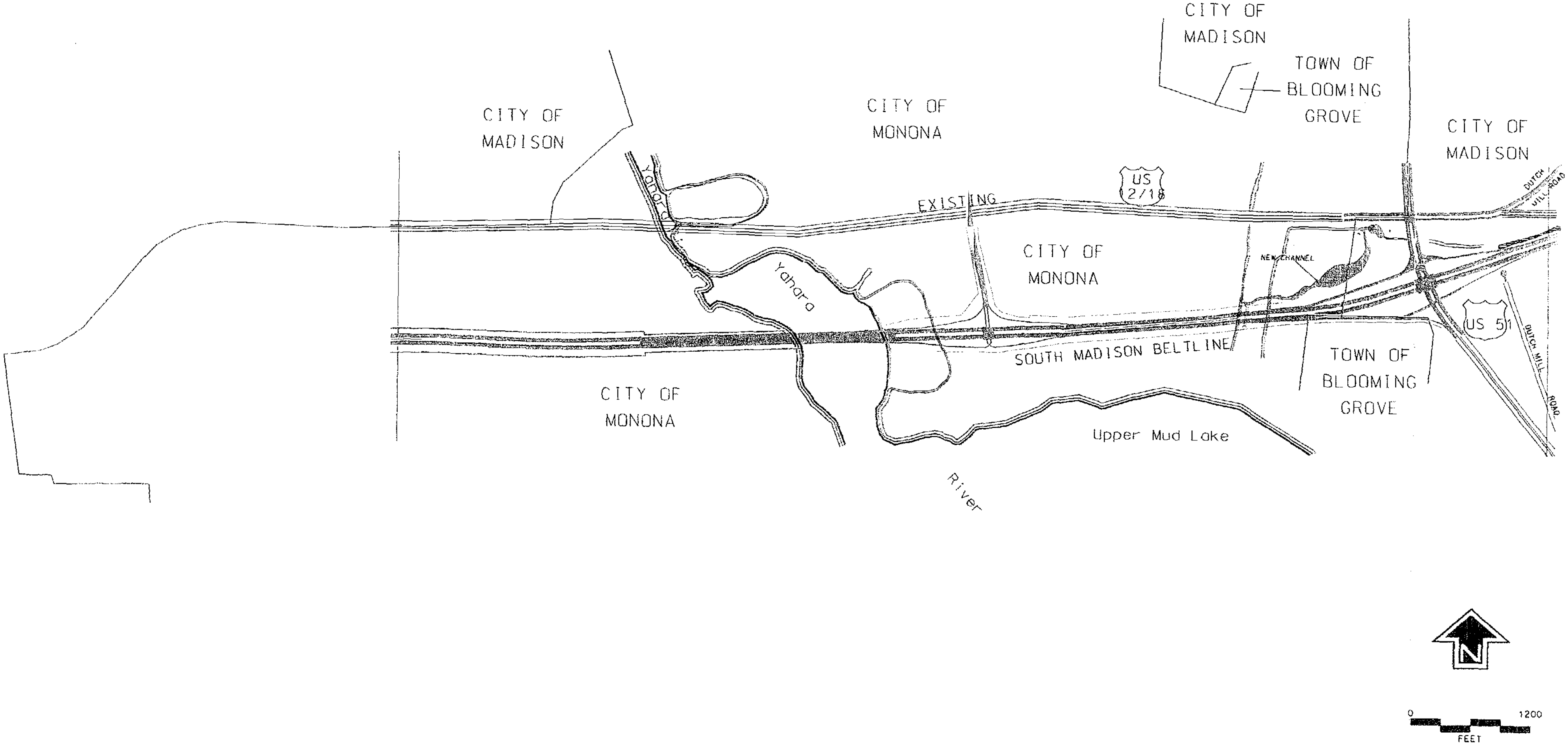



EXHIBIT 5-5: POLITICAL BOUNDARIES

west (right) bank of the river. Moving westward, after crossing the river, 701m (2,300 feet) of flat, low-lying marsh is traversed. This marsh is referred to as the Yahara River Marsh or Monona.

The soils in the corridor range from hydric to upland forest. However, Houghton muck, a hydric soil, dominates the corridor (Exhibit 5-6). Along the streambed of the Yahara River, silts and sands are found. Owing to the low velocity of the river, larger particles are rarely encountered. As the elevation increases, as it moves away from the river, forest soils begin to dominate. These include Dodge, St. Charles, Virgil, and Wacousta silt loams. The forest soils were farmed initially and are now covered by urban development. The farming and construction difficulties associated with highly organic soils, such as Houghton muck, limited their development.

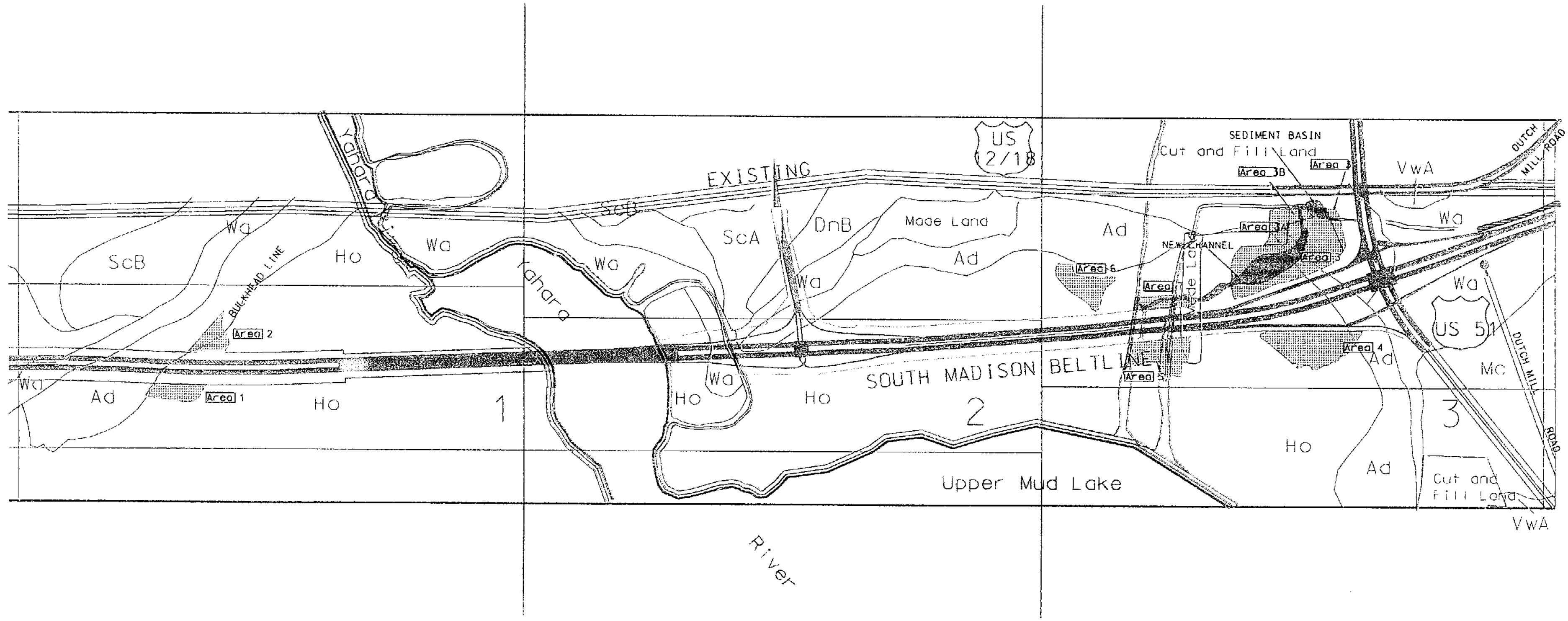
The vegetation of the corridor is dominated by Bluejoint grass, sedge meadow, cattails, reed canary grass and, in the higher elevations, some woody vegetation such as oak, box elder, and cottonwood (Exhibit 5-7). Following the cessation of farming or other uses, the plant communities were left to develop on their own. Fire or other land management techniques were not applied.

The wetlands of the Yahara River Marsh are characterized by Bedford et al. (1974) in accordance with predominant plant groupings:

- Deep marsh, mostly stands of narrow leaf cattail
- Shallow marsh, stands of various plants, alone or mixed
- Sedge meadow, with sedges and Bluejoint grass
- Dry sedge meadow with forbs
- Shrubs

Based on a field survey of the marshes, Bedford et al. (1974) reported that

> The west side marsh [west or right bank of the Yahara River] is a large peat bed. ...The open water where the river widens is noted as a place to watch migrating ducks in spring....The east side wetland is mostly sedge meadow on peat, and is drier than the west side. There are several small ditches, a large area where shrubs and some trees are invading, and a large reed canary grass area. Along the river edge is a wider, narrow-leaf cattail strip than is found on the west side of the river. There appears to be considerable woodcock habitat here: breeding snipe and woodcock were noted. Much of this area offers fair isolation from human disturbance.
>
> On the west side, dominant plants in separate and mixed stands are cattail, bur reed, lake sedge, Bluejoint grass, various wetland forbs, shrub willows, and red-osier dogwood. Some bog birch, a stand of cordgrass, and a few stands of giant reed were noted. Numerous muskrat houses and bullfrogs were seen.
>
> An interesting plant community of sedges on floating mat was found on the far west side.




| | |
|---|---|
| Ad* | Adrian muck |
| DnB | Dodge silt loam, 2 to 6 percent slopes |
| Ho* | Houghton muck |
| Mc* | Marshan silt loam |
| ScA | St. Charles silt loam, 0 to 2 percent slopes |
| ScB | St. Charles silt loam, 2 to 6 percent slopes |
| VwA | Virgil silt loam, gravelly substratum, 0-to 3 percent slopes |
| Wa* | Wacousta silty clay loam |
| * | Hydric |

Restored Wetlands

EXHIBIT 5-6: SOILS MAP

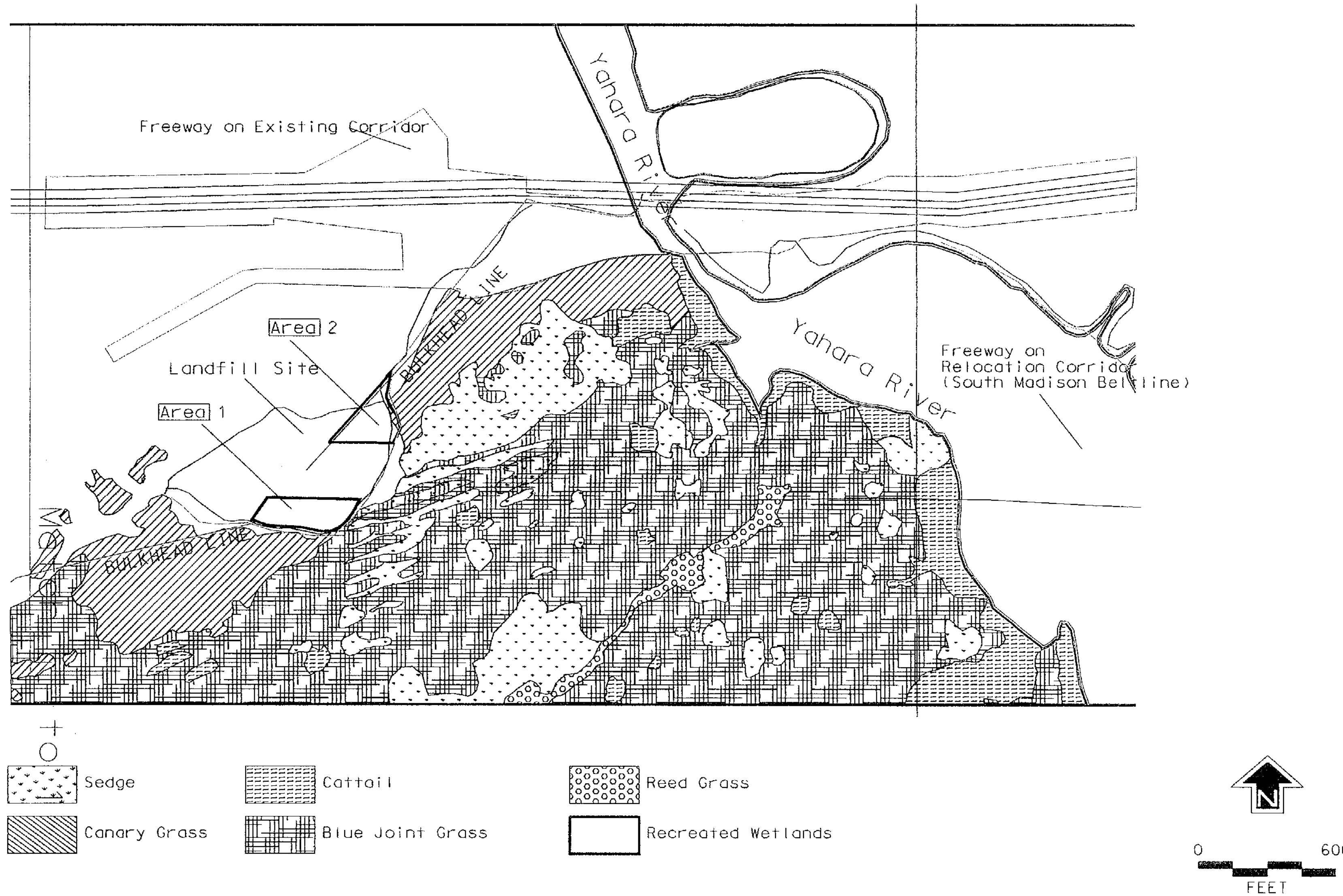



EXHIBIT 5-7: PLANT COMMUNITIES

Along the edge of the river much of the narrow leaf cattail strip is on a built-up organic material which is dry enough for jewel weed to invade.

The big wooded island on the west side contains a mixture of burr and black oak, black cherry, basswood, yellow bud hickory, and aspen. Probably both prairie relics and forest wildflowers exist there because summer access by people and cattle is unusually difficult.

On the east side of the river are large areas of sedge and Bluejoint. Near the river are stands of narrow leaf cattail. Willows, red-osier dogwood, and aspen are heavily invading a ten-acre plot as well as surrounding areas.

By and large, cattail, Bluejoint grass, lake sedge, red-osier dogwood, and reed canary grass cover most of the wetland area. A similar distribution of plant communities existed along the highway corridor. Of the 8.9 ha (22 acres) of wetlands scheduled to be lost to the freeway, 10 percent were dominated by sedges, 40 percent by cattail, and 46 percent by reed canary grass.

The wetlands that were traversed by the highway were by no means pristine. In 1940, a dam was built across the Yahara River at the outlet of Lake Waubesa, downstream of the project, which altered the hydrology of the entire area. The plant communities adapted and new wetlands emerged. Subsequently, urbanization altered the hydrology of the local drainage areas, and the edges around the marshes were filled for commercial and transportation purposes and waste disposal. Several commercial enterprises had pushed materials out into the marsh in order to make more room for storage adjacent to their properties. Foundry sand was dumped as waste in the marsh as well as construction debris and other rubble.

## MITIGATION IMPLEMENTATION AND RESULTS

Scientists from a number of agencies and the University of Wisconsin participated in discussions on how to best mitigate wetlands impacts. The FWS sought the establishment of open water marshes to be used for waterfowl and to provide year-round fish habitat. Scientists from the University of Wisconsin were particularly concerned with plant diversity and focused on the restoration of sedge communities within mitigation areas. The WDOT hired several graduates of the University of Wisconsin to work on the mitigation plan and to coordinate the Department's efforts with the WDNR, the FWS, and the COE. In the end, a plan was developed that met the requirements of these agencies.

### Objective

The broad objective of the mitigation plan was to create wildlife habitat (principally for fish, waterfowl, and those animals associated with sedge meadows), not just wetlands. This objective, which was not explicitly stated, was assumed to be achieved given the creation of high-quality wetlands.

### Definition of High-Quality Wetlands

The definition of high-quality wetlands was taken from Bedford et al. (1974) and includes the following characteristics:

- High water quality (including lack of silt or excess nutrient input)
- Natural water level cycle [hydrograph]
- Plant and animal species diversity
- Structural diversity (i.e., mix of tall and short plants, open water and marshes)
- Edge gradation (created by gradual slopes)
- Absence of nonnative or exotic species

The plan went on to call for specific measures to offset the wetland losses:

1. Recreating 8.0 ha (20 acres) of wetlands and enhancing an additional 2 ha (5 acres) of existing wetlands;
2. Creating a sediment pond to trap contaminants and improve water quality of storm water runoff before entering Upper Mud Lake;
3. Acquiring all privately owned wetlands between Upper Mud Lake and the existing Broadway transportation corridor--these lands would be retained in public ownership for long-term protection.

The WDOT committed to meeting the goals and objectives by acquiring land, restoring wetlands that had been destroyed or modified in the recent past, and conveying the property along with other sections of the Yahara Marsh to public ownership. The city of Monona became the management agency.

The WDOT undertook the mitigation work with the direct involvement of the team of scientists (university, contractors, and staff) responsible for preparing the mitigation plan. The excavation and planting contracts were part of the general contract issued for construction of the roadway. However, this contractual arrangement ignored a suggestion made by the Wisconsin Wetlands

Association that a separate contract be issued for the mitigation work. In the end, it proved to be troublesome--the general contractor had little experience with wetland restoration. Construction engineers, along with the design team, had to oversee the restoration activities.

**Wetland Restoration Phase**

The aggregate amount of land in the mitigation program was 49.4 ha (122 acres). The wetland restoration component of the mitigation plan consisted of 10 separate projects, numbered 1 through 7 and 3a, 3b, and 3c (Exhibits 5-8a through 5-8d). They were distributed along the highway corridor near the affected wetlands and connected by the marsh matrix in which they were placed. The area of these projects totaled approximately 7.5 ha (20 acres), which, as it turned out, exceeded the area of filled wetlands. After the EIS was prepared, it was determined that only 7.4 ha (18.3 acres) of wetlands were displaced, as opposed to the reported 8.9 ha (22 acres) (WDOT, 1984).

Of the restored area, approximately 1.1 ha (2.7 acres) (14 percent of the total) were reclaimed from a foundry sand dump. Fill from a miniature golf course was removed to create 4.0 ha (9.9 acres) (50 percent of the total), an old auto salvage yard was reclaimed to create 1.33 ha (3.3 acres) (17 percent), and demolition debris was removed to restore 1.05 ha (2.6 acres) (13 percent of the total). The remaining 0.61 ha (1.5 acres) (6 percent) were created from weed-infested, abandoned agricultural fields and highway embankments.

For each site, design objectives were established (Table 5-1). These objectives covered plant species and diversity and habitat structure, ranging from shallow marsh to open water. The plant species for each of the design objectives and the two planting phases are given in Tables 5-2 through 5-4.

Three vegetation establishment methods were considered in the planning phase: 1) natural recolonization, 2) planting, and 3) transplanting marsh sod. Exclusive use of natural recolonization was discounted because of the possibility of large-scale invasion by aggressive, nonnative plants, such as purple loosestrife, or the creation of cattail monocultures. Planting, on the other hand, was viewed as possibly limiting plant diversity owing to the small number of wetland plants commercially available. The contractor might have been asked to hand collect the desired species, but the environmental impact of this activity, given the large number of plants needed, was thought to be significant. Spreading the upper layer of excavated marsh soil on restoration sites having similar hydrologic conditions was expected to introduce a rich seed bank and a large quantity of native root stock at the new site. The macro and micro flora and fauna of the soil environment also were expected to be moved in the soil. It was concluded that a solid layer of excavated marsh soil would discourage growth from the underlying seed bank, which was predominantly reed canary grass. Germination experiments showed that the seeds in the marsh soils were still viable.

**Grading**--Grading plans were based on one principle: gradual slopes. The surrounding slopes of natural marshes and many palustrine wetlands are very flat. Most of the slopes in the restoration sites were less than 2 percent (Owen et al., 1989). The degree of elevation and slope dictates the water depth at a given point, which, in turn, dictates the plant species that will inhabit the location. Gradual slopes encourage stable plant communities, which are adapted to seasonal water level fluctuations. Completely flat wetlands might lack plant diversity.

Wherever possible, contour grades were drawn with no more than a 1:50 slope. This meant that the larger wetland restoration sites could include a range of wetland types, from sedge meadows to deep marsh. The drier wetland types were planned for smaller sites. Slopes as steep as 1:10 were used for up-gradient wetland restoration zones to reduce the area subject to invasion by upland pioneer species. Deep water restoration areas and wildlife ponds in existing wetlands were also designed with steep slopes to discourage vegetation growth and conserve space. Open water areas were given natural-looking shapes in order to enhance aesthetics. Irregular shorelines also create more habitat for waterfowl.

**New Techniques**--To minimize impacts on the marsh, the bridge over the Yahara River and road embankment through the adjoining wetlands were constructed from the bridge deck and road surface using end-on techniques new at the time. That is, the embankments, foundation structures, support columns, and bridge deck were constructed without entering the marsh. Equipment and materials were advanced along the completed bridge and road sections.

**Water Levels**--Early in the construction planning phase, an investigation was launched into the possibility of regulating water levels of the Yahara River, which would in turn affect water levels in the mitigation sites. The idea was to use the dam and control structure on the outlet of Lake Waubesa, 6 km (2.3 miles) downstream of the restoration sites. This would afford a very quick and easy way of achieving the desired hydrologic effects. In fact, if properly managed, some of the excavation might have been avoided--the water level could have been raised rather than the land lowered, but this would have affected other areas as well. The WDNR, among others, did not look favorably upon the idea because of the interference with recreational and wildlife uses. The WDOT was also concerned about the long-term management requirements of manipulating water levels. As a result, this idea was abandoned.

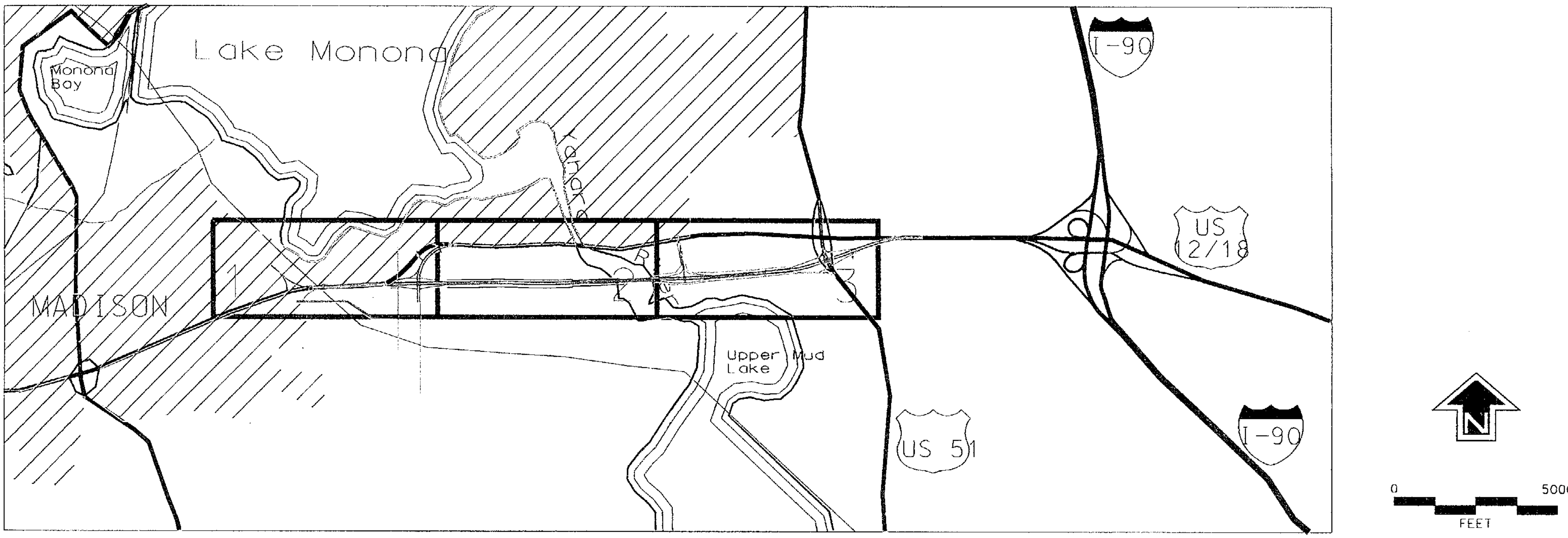



EXHIBIT 5-8a: WETLAND FILL AND MITIGATION SITE INDEX

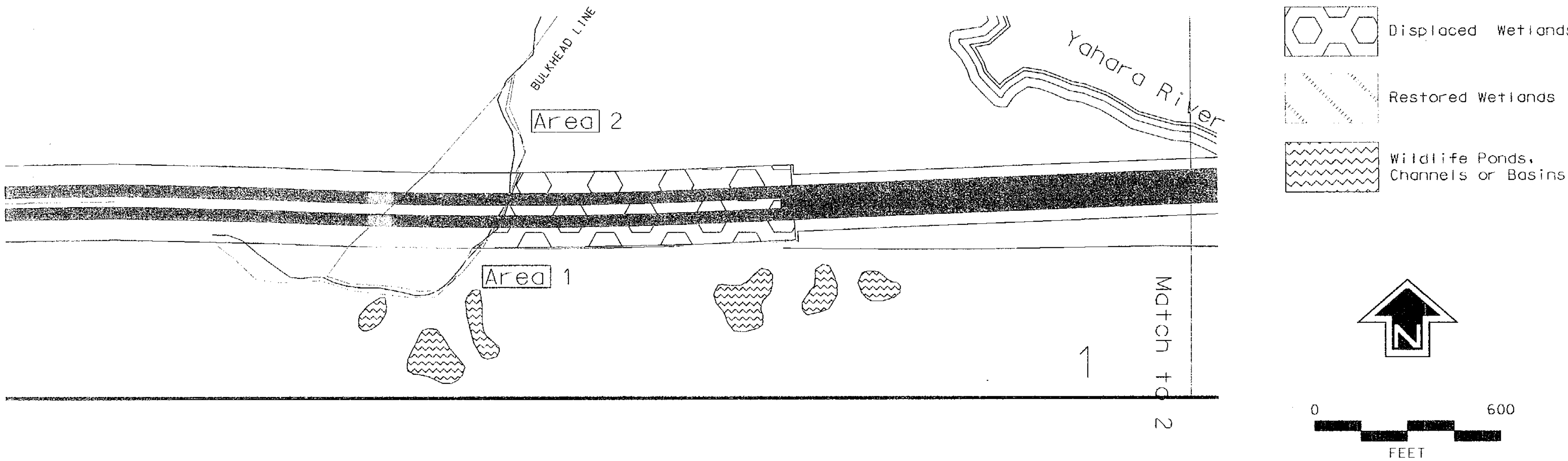



EXHIBIT 5-8b: WETLAND FILL AND MITIGATION SITES 1 AND 2

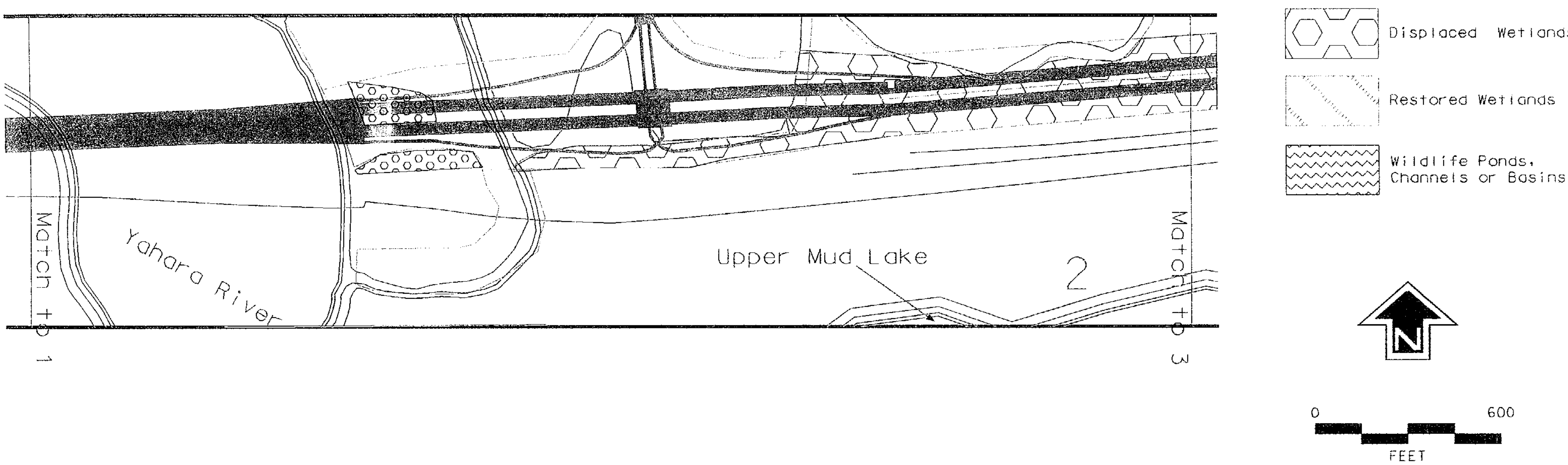



EXHIBIT 5-8c: WETLAND FILL

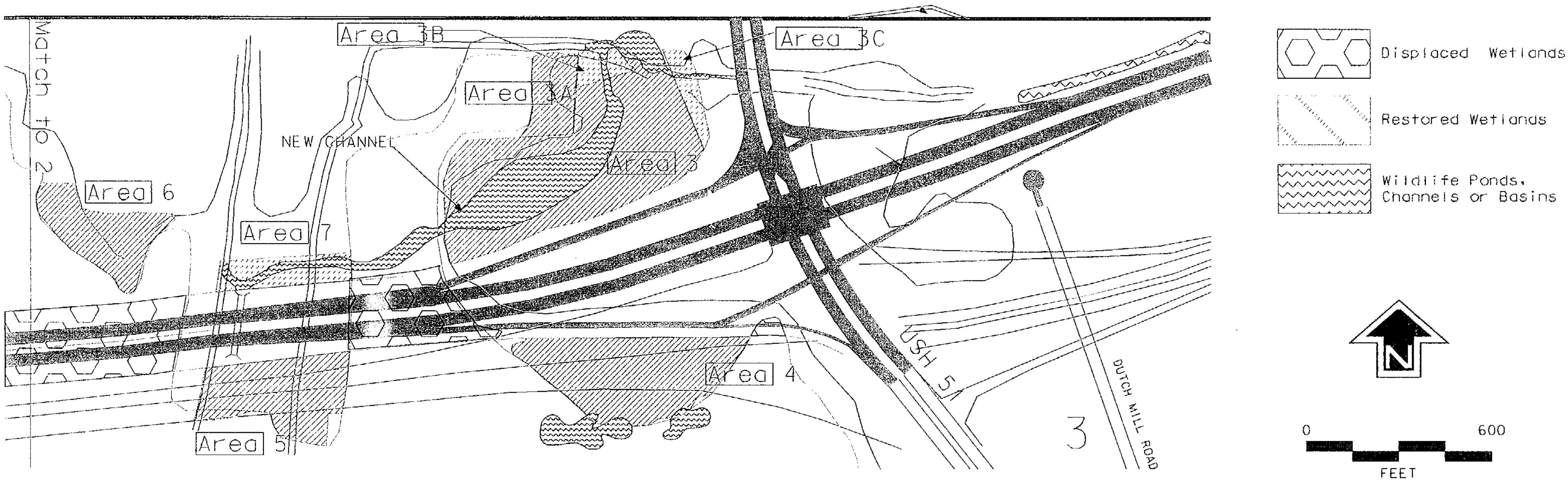



EXHIBIT 5-8d: WETLAND FILL AND MITIGATION SITES 3-7

## Table 5-1: Restoration Areas and Design Objectives

| Wetland Number | Acres | Hectares | Premitigation Status | Design Objectives |
|---|---|---|---|---|
| 1 | 2.2 | 0.9 | Foundry sand dump | Shallow marsh |
| 2 | 0.5 | 0.2 | Foundry sand dump | Shallow marsh |
| 3 | 7.6 | 3.1 | Miniature golf course fill | Shallow and deep marsh and open water |
| 3a | 1.0 | 0.4 | Agricultural land | High and shallow marsh |
| 3b | 0.0 | 0.0 | Agricultural land | Detention basin |
| 3c | 0.5 | 0.2 | Highway embankment | High and shallow marsh |
| 4 | 2.3 | 0.9 | Miniature golf course fill | High and shallow marsh and open water |
| 5 | 1.6 | 0.6 | Auto salvage yard fill | High, shallow, and deep marsh |
| 6 | 2.6 | 1.1 | Demolition debris fill | High, shallow, and deep marsh |
| 7 | 1.7 | 0.7 | Auto salvage yard fill | Deep marsh |
| TOTAL | 20.0 | 7.5 | Road opened in December 1988 | |

## Table 5-2: Wetland Species Planted in Phase 1 Mitigation

| Common Name | Scientific Name |
|---|---|
| | Zone 1: Shallow Marsh (0.5 to 1.0 ft of water) |
| Bur reed | Sparganium eurycarpum |
| Duck potato | Sagittaria latifolia |
| Marsh smartweed | Polygonum muhlenbergii |
| Pickerelweed | Pontederia cordata |
| River bulrush | Scirpus fluviatilis |
| Sweet flag | Acorus calamus |
| | Zone 2: Deep Marsh (1 to 2 ft of water) |
| Deepwater duck potato | Sagittaria rigida |
| Hardstem bulrush | Scirpus acutus |
| Sage pondweed | Potamogeton pectinatus |
| White water lily | Nymphaea tuberosa |
| Wild celery | Vallisneria spiralis |
| | Zone 3: High Marsh (0 to 1.5 ft above water table) |
| Common reed grass | Phragmites communis |
| Prairie cordgrass | Spartina pectinata |

Source: Crabtree, 1992.

## Table 5-3: Wetland Species Planted in Phase 2 Mitigation[a]

| Common Name | Scientific Name |
|---|---|
| **Annuals** | |
| Jewelweed | Impatiens biflora |
| Willow weed | Polgonum lapathifolium |
| Smartweed | Polygonum pennsylvanicum |
| **Perennials** | |
| Angelica | Angelica atropurpurea |
| Marsh milkweed | Asclepias incarnata |
| New England aster | Aster novae-angliae |
| Bluejoint grass | Calamagrostis canadensis |
| Joe-pye weed | Eupatorium maculatum |
| Boneset | Eupatorium perfoliatum |
| Water smartweed | Polygonum coccineum |
| Mild water pepper | Polygonum hydropiperoides |
| Mountain mint | Pycnanthemum virginianum |
| Marsh dock | Rumex orbiculatus |
| Wool grass | Scirpus cyperinus |
| Meadow rue | Thalictrum dasycarpum |

Source: Crabtree, 1992.

[a]Seeding rate = 2.27 kg/ha (2 lb/acre); seeded in high and medium marsh zones.

## Table 5-4: Wetland Species Planted in Phase 2 Mitigation

| Common Name | Scientific Name | Zones[a] |
|---|---|---|
| Lake sedge | Carex lacustris | H, M |
| Tussock sedge | Carex stricta | H, M |
| Sedge | Carex hystericina | H, M |
| Bluejoint grass | Calamagrostis canadensis | H, M |
| Prairie cordgrass | Spartina pectinata | H |
| Blue flag iris | Iris shrevei | H |
| Bur reed | Sparganium eurycarpum | M, L |
| River bulrush | Scirpus fluviatilis | M, L |
| Soft stem bulrush | Scirpus validus | M, L |
| Duck potato | Sagittaria latifolia | M, L |
| Arrowhead | Sagittaria rigida | L |
| Hard stem bulrush | Scirpus acutus | L |

*Source*: Crabtree, 1992.

[a] H = high marsh, M = medium or shallow marsh, L = low or deep marsh.

**Using Marsh Soils**--The idea of using excavated marsh soil, largely Houghton muck, proved successful. The material was removed from the highway right-of-way and spread on selected restoration sites (Exhibit 5-9). When road construction preceded wetland restoration, the topsoil was stockpiled. After several trials of distributing the excavated marsh soil, the best technique involved excavating a small area of the filled material from the restoration site, approximately 15.2 cm (6 inches) below the final grade, and then distributing the marsh soil. The excavating equipment was then moved back, and more fill material was removed and marsh soil distributed. Some work was done during the winter when the ground was frozen, and this facilitated the movement and final grading of the marsh soil.

A range of construction techniques was employed. Of the 10 restoration work sites, seven involved the removal of unwanted material: foundry sand, uplands soil fill, or debris. In two cases, 3a and 3c, in sites that were formerly agricultural land, only shallow grading was required. The grading was used to remove the top few inches of soil in order to rid the site of reed canary grass. The excavated materials from sites 4 and 7 were disposed in the road embankment when suitable for such construction. The other materials were hauled off site and disposed in landfills.

Sites 1, 2, 3, and 4 were excavated and marsh soil spread during the first year of construction, September 1985 through September of 1986. The remaining sites were constructed after the road embankment was complete and no marsh soil was available. Consequently, sites 3a, 3b, 3c, 5, 6, and 7 required a different planting scheme. For those sites receiving the marsh soil, it was assumed that the seed and plant materials were in the soil and that they were viable, which was generally the case. For the other areas, because they were not excavated to the depth of the old, underlying marsh soils, the remaining surface soils were believed to contain only weeds or no viable plant materials. Consequently, these sites were planted with rootstock and seeded with a cover crop.

**Problems**--Some difficulties arose during restoration work. Wrong species of plants were delivered in some cases and in others the rootstock was unacceptable. Elevations had to be closely monitored. However, as construction proceeded, these problems were readily overcome because of the presence of trained wetland scientists.

Once the mitigation landscapes were established and planted, the results depended upon the ensuing hydrologic conditions and on the physical and biological interactions between the new soil surfaces and the hydrology, plants, and wildlife. Work started on the restoration sites in September 1985 and was completed by May 1988. The highway was open for traffic in December 1988.

Although monitoring was not required by the COE, the WDOT did monitor selected restoration sites for 2 years (Jackson, 1990). Also, studies were undertaken by graduate students and faculty of the University of Wisconsin (Owen et al., 1989; Ashworth, 1992) and independent contractors (Crabtree, 1990). These studies focused on selected restoration areas and compared them to referenced sites located in the Yahara Marsh.

| Wetland number | Acres | Hectares | Pre-mitigation status | Design objectives |
|---|---|---|---|---|
| 1 | 2.2 | 0.9 | Foundry sand dump | Shallow marsh |
| 2 | 0.5 | 0.2 | Foundry sand dump | Shallow marsh |
| 3 | 7.6 | 3.1 | Miniature golf course fill | Shallow and deep marsh and open water |
| 3a | 1.0 | 0.4 | Agricultural land | High and shallow marsh |
| 3b | 0.0 | 0.0 | Agricultural land | Detention basin |
| 3c | 0.5 | 0.2 | Highway embankment | High and shallow marsh |
| 4 | 2.3 | 0.9 | Miniature golf course fill | High and shallow marsh and open water |
| 5 | 1.6 | 0.6 | Auto salvage yard fill | High, shallow and deep marsh |
| 6 | 2.6 | 1.1 | Demolition debris fill | High, shallow and deep marsh |
| 7 | 1.7 | 0.7 | Auto salvage yard fill | Deep marsh |
| Total | 20.0 | 7.5 | | |

Road opened in December 1988

EXHIBIT 5-9: RESTORATION AREAS AND DESIGN OBJECTIVES

**Plant Growth**--As reported by Day (1986), wetland vegetation began to emerge from the spread marsh soil early in April 1986. Sedges were first, followed by cattail, then bur reed and arrowhead. These plants and others prospered through the summer, and by September they had reached heights of .91 to 1.82 m (3 to 6 feet). Still, Day expressed concern for the fragile nature of these newly developing ecosystems.

Over two growing seasons, the plant community in the restored areas continued to develop, but somewhat differently from that found in reference areas. For example, sedges and Bluejoint grass were notably absent in Area 3, whereas they were frequently found in reference areas, but the presence of cattail was similar for both reference and mitigation areas. Further, the reference areas had fewer nonnative species than the mitigation areas. Day (1986) attributed some of these differences in Area 3 to

> ....a 'younger' community than the source wetland in terms of ecological succession. Even though all the rootstock from the source wetland was present in the salvaged marsh surface (SMS), the growing conditions in Area 3 (i.e., exposed mud flats) favored the pioneer species present in the seed bank. The straw mulch specified for these areas was originally intended to shade the exposed mud flats and favor growth from rootstock. Unfortunately, data are insufficient to evaluate differences between mulched and unmulched areas. In any case, the mulch layer specified was probably too thin to duplicate the influence of a normal detritus layer along with the standing dead stems found in a well established marsh. Restoration Area 3 has only been through one growing season. Its character could change significantly over the next several years.
>
> The second explanation is that the hydrologic regime of Area 3's SMS zone is quite different from that of the source wetland. The average substrate elevation in the sampled portion of Area 3 is 257.43 m (844.6 feet) msl. The average elevation of the source wetland was 257.65 m (845.3 feet) msl. The difference in elevation, i.e., deeper water, seems to have discouraged colonization by sedges and Bluejoint grass. This was anticipated but not to the extent that it occurred. The actual range of substrate elevations is approximately one-half foot lower than the intended range. This is probably due to the difficulties involved with detailed grading underwater.

**Wildlife Attraction**--The new plant communities attracted a wide range of wildlife within their first year of existence. Mallards, pied-billed grebes, blue-winged teal, and the ever-present Canada geese occupied the open water areas. They used the habitat for breeding and foraging. A large population of migratory shorebirds, such as greater yellowlegs and dowitchers, found the mud flats attractive habitat. Green and great blue herons, both wading birds, were seen in and around the restoration sites during the summer. Chorus and pickerel frogs, turtles, and small forage fish moved into the newly created landscapes from surrounding habitat. Muskrats colonized Areas 2, 3, and 4, causing some concern because of their habit of eating young plant shoots. Because trapping was ruled out, their presence was tolerated.

In the early stages (i.e., the first 2 years), the monitoring program revealed the failure of certain plants to propagate, which required a second planting. This was done in 1992, in the mitigation areas 5, 7, and 9. In other cases, the desired plant communities failed to develop but hydrophytes prospered. Unfortunately, a drought occurring in the second year contributed to the rapid expansion of less desirable wetland plants, such as cattail and the nonnative canary grass.

Management included some manipulation of hydrology. Irrigation was used at the early stages of reestablishing plant communities. In large, however, the hydrology of the marshes was left up to the existing climatic conditions and the normal effects of the dam on Lake Waubesa. Fire was used but only to a very limited extent. Grazing by muskrats and other herbivores was not controlled or limited. Attempts, however, were made to prevent geese from consuming the early plantings.

Day (1986) noted several problems with the execution of the construction plan:

- If grading of the marsh soil resulted in high spots, often these areas were colonized by woody species and later by undesirable weeds.

- In some cases, the spread marsh soil resulted in a healthy, viable plant community whereas, in the same location, plantings failed with no apparent explanation.

- Deposition of suspended sediment over previously graded and planted landscapes, in isolated cases, led to colonization by undesirable plant species.

- In some cases, a planting grid with 6-foot centers left open areas that were quickly colonized by weedy species.

After the project was concluded, wetlands had been established in all the mitigation areas, but they did not meet the design specifications in every case (Exhibit 5-10). Reed canary grass and other invasive, nonnative species are more abundant than the original specifications called for. Still, the restored wetlands provide wildlife habitat, flood control, and water quality management, and they are open and available to public use and appreciation. The lands are being managed by the Monona Park District. And although the district currently does not actively manage the marsh complex, the administrative and managerial mechanisms exist for correcting any problems that might arise.

| Common Name | Scientific Name |
| --- | --- |
| | Zone 1: Shallow Marsh (0.5 to 1.0 ft of water) |
| Burreed | *Sparganium eurycarpub* |
| Duck Potato | *Sagittaria latifolia* |
| Marsh Smartweed | *Polygonum muhlenbergii* |
| Pickerel Weed | *Pontederia cordata* |
| River Bulrush | *Scirpus fluviatilis* |
| Sweet Flag | *Acorus calamus* |
| | Zone 2: Deep Marsh (1 to 2 ft of water) |
| Deepwater Duck Potato | *Sagittaria rigida* |
| Hardstem Bulrush | *Scirpus acutus* |
| Sage Pondweed | *Potamogeton pectinatus* |
| White Water Lily | *Nymphaea tuberosa* |
| Wild Celery | *Vallisneria spiralis* |
| | Zone 3: High Marsh (0 to 1.5 ft above water table) |
| Common Reedgrass | *Phragmites communis* |
| Prairie Cordgrass | *Spartina pectinata* |

EXHIBIT 5-10: WETLAND SPECIES PLANTED IN PHASE 1 MITIGATION (CRABTREE, 1992)

## CONCLUSIONS

According to scientists of the COE, the WDNR, and WDOT, the mitigation project was successful. Both the FWS and the WDNR were satisfied with the protection and gain in wildlife habitat. This, in the end, was the goal and the primary wetland function considered both in the mitigation design and in the perceived value of the work. Areas that had been filled or drained were restored to wetland, and acceptable plant communities were established. Wetlands were created and the Yahara River Marshes and the associated plant and animal life survived and were even enhanced. Flood control and water quality benefits are present, as demonstrated by the monitoring program.

The worst fears of the opponents to the highway project were not realized. The wetlands adjoining the project, but outside of the impact area, were not adversely affected by the highway. The restored and enhanced wetlands are considered successful, despite the fact that the plant communities that eventually developed in these areas were not exactly as the designers had intended. Still, given that this was the first wetland mitigation project undertaken by the WDOT, it represents an important advancement in restoration science.

From one perspective, only the restored and created wetlands might be counted as a contribution to the wetland resources of the area. In this case, the gain to loss ratio would be 1:1, assuming that the gained wetlands function as well as those that were lost. However, wetland resources were also improved through enhancement and protected from future development, contributing to the region's long term, sustainable wetlands resources.

Besides the physical contribution to the resource base, more was gained from the mitigation experience. This was the first time in Wisconsin that mitigation for wetland losses was required. Thus, it was the first time that the WDOT engaged in the protection and construction of new or enhanced wetlands. The construction techniques used in this effort were new and expensive. But despite the lack of experience, the mitigation was accomplished and the participants were satisfied that functional capacity and wetlands values were added to the regional environment.

## ACKNOWLEDGMENTS

A number of people had a hand in protecting the Yahara Marsh and advancing the idea of its importance to the environment. They helped to minimize wetland losses and to ensure that what losses occurred were properly mitigated. Early on, James Zimmerman, a professor with the University of Wisconsin, and his wife, Libby, along with a number of graduate students, most notably Barbara Bedford, highlighted the value of the Yahara Marsh and recommended its preservation. Professor Zimmerman and his wife started the Wisconsin Wetlands Association and worked to draw public attention to the problems posed by a road traversing the marsh. In these efforts, they were joined by many others.

Mr. John Jackson, a biologist with the WDOT, labored for a number of years to improve the design of the highway in order to minimize wetland losses. He, along with a team of engineers and scientists, negotiated the final mitigation agreement. Ms. Betsey Day, a graduate student at the University of Wisconsin and a biologist with the WDOT, prepared the mitigation design and helped shepherd the restoration work. She undertook construction supervision and baseline surveys. She also helped to evaluate the effectiveness of the various restoration techniques employed.

Mr. Hal Meier, John Jackson's counterpart with the WDNR, initially opposed the project, but after it gained public support he worked closely with the other environmental scientists to ensure the best possible outcome. He worked many years on the resolution of the transportation issues and maintained a keen interest in the restored landscape. Ms. Katherine Falk, the Public Intervener, helped to crystallize the issues over whether or not to build the highway and, in the end, her arguments appeared to set the stage for the final resolution.

Mr. John Jackson, Ms. Betsey Day, and Mr. David Siebert graciously helped the authors organize the materials and explain the facets of the Yahara River Marsh restoration. Their help is greatly appreciated.

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# CHAPTER 6

## HOOSIER CREEK WETLAND

U.S. Highway 285 runs between the steep escarpment of the Front Range of the Rocky Mountains and the North Fork of the South Platte River near Denver, Colorado. Last improved in 1940, this road had two 3.3-meter (m) (11- foot) lanes. The shoulders were narrow and unpaved and the tight curves made driving hazardous in both summer and winter. In 1986, improvements were proposed for a 7.5-kilometer (km) (2.9-mile) stretch of this road between Grant and Webster, Colorado (Exhibit 6-1).

The need for the improvements was largely driven by safety, such as reducing sharp curves and widening and paving the shoulders, and consideration of future traffic demand. U.S. 285 serves as a major traffic artery for the Denver metropolitan area. Although the rural population of Park County was not growing rapidly, the burgeoning population of neighboring Jefferson County created a demand for access to recreational areas in Park County.

The Colorado Department of Transportation (CDOT) undertook design of the road improvements. Within the immediate planning horizon, additional traffic on the road was not expected, but because the road was being improved for safety reasons, the Department concluded the road should be widened to two 3.66-m (12-foot) lanes with 3.05-m (10-foot) shoulders. However, to widen the roadbed, either the face of the escarpment on the north side of the road would have to be excavated or the North Fork of the South Platte River would have to be moved south. To avoid possible rock falls and maintenance costs associated with excavation of the escarpment, the Department concluded that relocating the river was safer, less costly and, ultimately, less environmentally damaging.

Because the river flowed through a narrow valley between the roadbed and an abandoned railroad embankment, very little space was available for widening. To maintain the hydraulic capacity of the river, the channel section had to be deepened and widened. This, in turn, caused the loss of 0.97 hectares (ha) (2.4 acres) of wetland (Meiring et al., 1991).

The CDOT proposed to mitigate the wetland losses both on- and offsite. Although the Department committed only to replace the wetland losses on a 1:1 basis, a greater area was restored or created. Approximately 0.61 ha (1.5 acres) of wetlands was created along the river corridor and an additional 1.3 ha (3.21 acres) was restored on Hoosier Creek, a tributary of the North Fork (Cooper, 1988). This latter, off-site mitigation is located approximately 2.41 km (1.5 miles) north of the highway right-of-way but within the same watershed as the impacts. The actual mitigation ratio was 1.5:1.

The design of the mitigation program was reviewed by the U.S. Environmental Protection Agency, the FWS, the U.S. Army Corps of Engineers (COE), and the Forest Service (FS) (the landowner of the off-site mitigation property). After an extensive search of possible off-site mitigation locations, the FS property was selected. It afforded a number of environmental benefits, some of which could not have been accomplished within the U.S. 285 right-of-way.

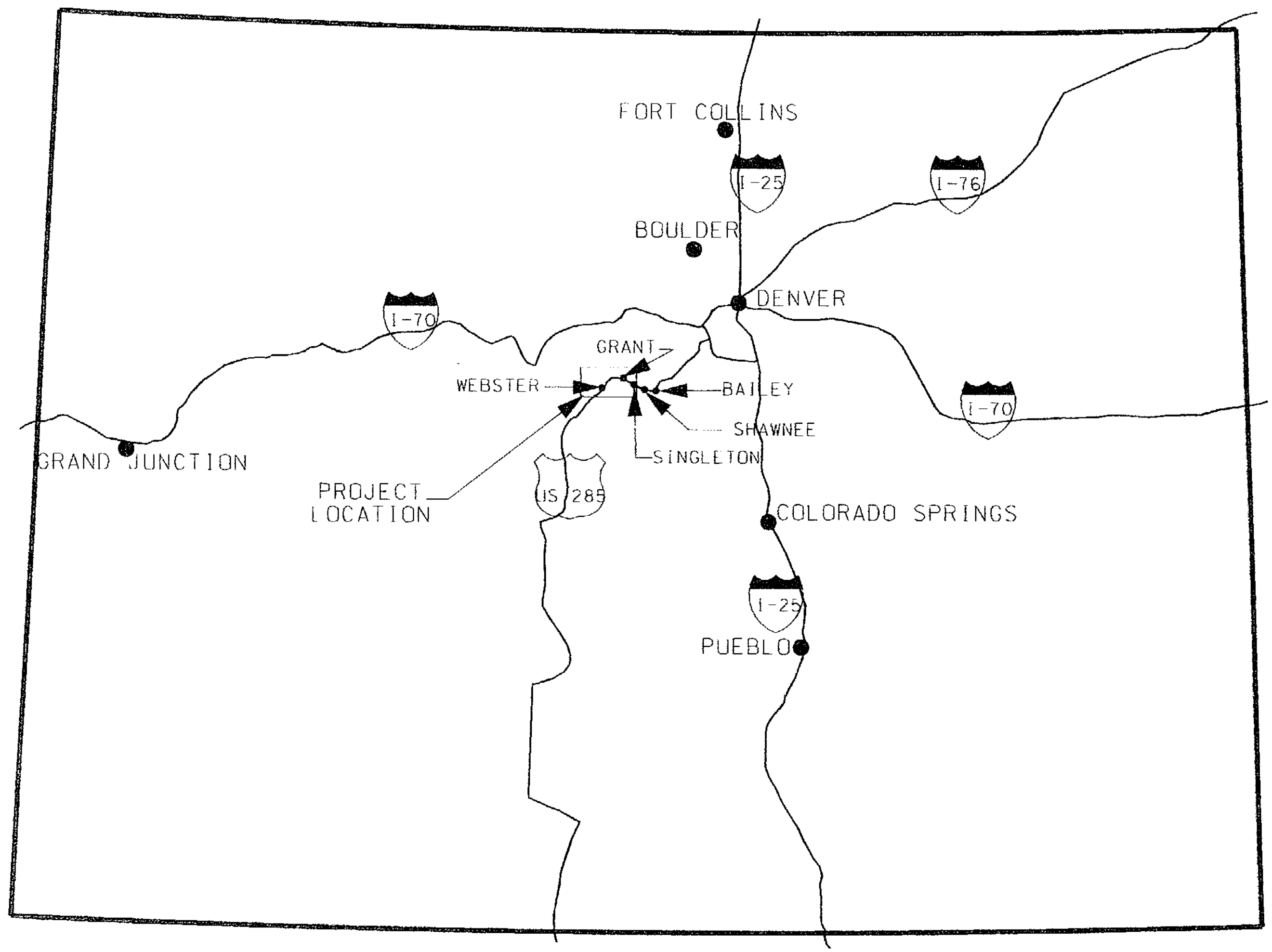



EXHIBIT 6-1: COLORADO

The proposed improvements to the highway, the environmental impacts, and the proposed restoration were reviewed by public and private agencies and local citizens' groups as well. On the whole, there was little opposition to the improvements, although major concerns were raised about the temporary contamination of public water supplies downstream of the project area during construction. For example, the Bailey Water and Sanitation District, located at Bailey, Colorado, pointed out to the Commander of the Omaha District of the U.S. Army Corps of Engineers (COE) (the Omaha District has responsibility for the South Platte Watershed), that their water intakes were downstream of the construction activities. The Water District anticipated that "...such major construction would increase our turbidity problems immensely" (Painter, 1988). The Upper South Platte Water Conservation District recorded a similar complaint (Butler, 1988), but went on to propose that through the wetland mitigation work associated with the project, water quality conditions on the North Fork of the South Platte River could be improved: "...channel realignment and wetland construction associated with the U.S. 285 improvement project can be modified to provide not only wildlife mitigation but also water quality mitigation provided all parties are willing to cooperate." The water quality problems alluded to were related to heavy metals--copper, lead, silver, and cadmium --being washed off nearby mining sites. The District proposed that the CDOT work with them to develop wetlands along the North Fork that could be used to remove or control the heavy metals. In addition, the Shawnee Water Commissioner's Association, in Shawnee, Colorado, raised concerns about the disturbance of mine tailings within the project and the possibility that these tailings might be conveyed to its intake and into its water supply system (Tolpo, 1988).

Only the Park County Planning Commission raised concerns about the loss of wetlands (Bowman, 1988). They also joined the Upper South Platte Water Conservation District in suggesting that all agencies cooperate to expand the objectives of the wetland mitigation program to improve water quality along the North Fork. The planning commission also pointed out that U.S. 285, through the Platte Canyon, "serves as a major route for metropolitan residents to reach and enjoy some of Colorado's finest outdoor recreation. Through this project, the possibility exists for a coordinated effort to begin between Colorado's Division of Highways and Division of Wildlife to improve the habitat within this corridor, possibly as part of the Governor's proposed 'Watchable Wildlife' program."

By February of 1987, when the CDOT submitted the Section 404 permit application to the Omaha District of the COE, it had, in effect, coordinated with the regulatory and oversight agencies to reach an agreement on wetland mitigation. Consequently, issues raised by these agencies in response to the public notice were of minor significance and typically became recommendations for conditions on the permit. For example, the Division of Wildlife in the Colorado Department of Natural Resources (CDNR) noted that "after extensive coordination on this project with the Colorado Highway Department, we are satisfied that this proposal will have minimum possible negative impacts on wildlife/fisheries habitat. We have no objection to the issuance of this permit" (Weber, 1988).

The FWS also endorsed the project, but asked that several conditions be included in the permit (Opdycke, 1988):

> Should mitigation of the 0.81 ha (2.0 acres) of wetlands [this was all that was needed although 1.3 ha (3.21 acres) was restored] proposed for Forest Service land along Hoosier Creek not occur for any reason, the Department should be required to find an alternate mitigation site as close as possible to the area of impacts and accomplish wetland mitigation in the amount originally proposed.

Additionally, we recommend the permit be conditioned to require the Department to provide draft copies of all mitigation plans to the resource agencies for review and comment. Plans for the 0.20 ha (0.5 acre) to be mitigated on site, the 0.81 ha (2.0 acres) on Hoosier Creek, and the plans prepared by the Department's consultants for the remainder of the construction corridor should be made available to the concerned agencies.

Further, the FWS concurred with the COE that there would be no effect on threatened and endangered species.

The CDOT responded to all issues raised by local, State, and Federal agencies and private citizens. The issues of increased turbidity and the transport of sediment-related solids were addressed directly and promises made to control the suspension and transport of sediments. Erosion control plans were included in the construction documents as required by the Section 404 permit. The CDOT agreed to the FWS' recommendations, and they were incorporated into the permit. However, the CDOT did not become involved in a wider effort to create additional wetlands over and above the highway project mitigation plan along the corridor to ameliorate the water quality problems and other issues presented by the various water supply districts downstream from the project site (McOllough, 1988). Federal Highway Administration policy did not allow for expenditures of Federal-aid highway funds for mitigation beyond what is required for impacts associated with Federal-aid highway projects.

Design work by the Department began in 1986. By the end of 1987, the design and environmental issues had been resolved. In March 1988, the COE issued the public notice for the project. The COE declined to hold a public hearing, although several requests were made. Instead, the issues raised by the public and affected agencies were directly addressed in writing by the CDOT. On June 10, 1988, the District Commander of the COE issued permit #CO 2SB OXT 2 010629. Construction work was initiated in this same year, as was mitigation. After a field inspection on February 7, 1990, by the project manager for the COE, the mitigation for the highway project was determined to be successful and complete.

## ENVIRONMENTAL AND SOCIAL SETTINGS

### Project Location

The highway improvement project is located in north-central Park County, approximately 80.47 km (50 miles) southwest of Denver. It is nestled in the valley of the North Fork of the South Platte River. The stream drains the western slope of the Front Range of the Rocky Mountains. The elevation range of the county is from 1,829 to nearly 3,658 m (6,000 to 12,000 feet). Grant, Colorado--the town situated within the project area--is at an elevation of 2,643 m (8,670 feet).

The project and the mitigation site are in the Front Range of the Rocky Mountains. These mountains are immediately west of Denver, stretching from Rocky Mountain National Park on the north to Pike's Peak on the south. The western boundary follows the Continental Divide from Long's Peak to James' Peak (Weber, 1976). The project area is situated within the subalpine plant community, between 2,682 and 3,353 m (8,800 and 11,000 ft) above mean sea level (msl). According to Weber (1976), this class is characterized by "Engelmann spruce, subalpine fir, and limber pine forest, interspersed with moist meadows, ponds, and bogs. Very rich in wildflowers."

### Temperatures

The annual mean temperature in Grant is 38.7°F. The annual mean daily maximum temperature is 53.3°F, and the annual mean daily minimum temperature is 24.1°F. January, the coldest month of the year, has a mean temperature of 20.9°F. July, the warmest month, has a mean temperature of 58.8°F. With a 70 percent probability, the frost-free growing season for agricultural crops is approximately 83 days, extending from June 16 through September 6. As Dr. David Cooper (1998) has noted, however, the growing season for native, subalpine plants, including hydrophytes, is a good deal longer because these plants have adapted to colder air and soil temperatures.

### Precipitation

Annual precipitation in Grant is 39.4 centimeters (cm) (15.5 inches) with a 30 percent probability that the annual total might be < 29.2 cm or >44.2 cm (<11.5 inches or >17.4 inches). Approximately 35 percent of the total amount of precipitation, or 13.7 cm (5.4 inches), occurs as snowfall. The wettest months are July and August, with 6.3 cm and 6.2 cm (2.49 and 2.43 inches), respectively. The driest months of the year are January and February, at 1.14 and 1.35 cm (0.45 and 0.53 inches), respectively. In the highest stream discharge period, May through August, 52 percent of the precipitation occurs.

The watershed of the North Fork at Grant is approximately 360 square km (127 square miles). The northwestern boundary of this drainage area falls along the border between Summit and Park Counties. After adjusting for the discharge into the North Fork from the Harold D. Roberts tunnel, which supplies water to the Denver Metropolitan area, the mean annual flow is 2.03 cubic meters per second (cms) (71.6 cfs) as measured below Geneva Creek at Grant, Colorado (United States Geological Survey, 1996). The annual yield is 19.6 cm (7.7 inches). Streamflow accounts for approximately 49 percent of the precipitation that falls on the watershed. Streamflow reflects precipitation/runoff patterns. More than 65 percent of the discharge occurs over the 120 days of the snowmelt season--May through August. The other 35 percent occurs September through April. This distribution is due in large part to snow accumulation at the higher altitudes and snowmelt during the late spring and early summer. The highest monthly mean flow–8.33 cubic meters per second (m/sec) (294 cubic feet per second (cfs))--occurs in June, and the lowest mean monthly flow–1.09 cubic m/sec (38.6 cfs)--occurs in March.

The high water yield relative to precipitation occurs primarily because of the low evapotranspiration due to moderate to low temperatures and the very steep slopes of the mountainous watershed. The inorganic soils on the mountain slopes have very low water retention capability. In the alpine valleys, on the other hand, organic matter tends to accumulate and the peaty soils have a greater capacity to retain water.

### Soil Types

The general soil association for the area is Herbman-Hiwan: "moderately sloping to very steep, shallow, well-drained, stony, gravelly, loamy, and sandy soils that formed in the material derived from igneous and metamorphic rocks" (Price and Amen, 1984). These soils are found on the side slopes and ridges of mountains where slopes range from 5 percent to 70 percent . Coniferous trees and shrubs and grasses account for most of the vegetation, and the soils exist mainly in the elevation range of 2,316 to 3,048 m (7,600 to 10,000 feet). This soil unit covers approximately one-third of the surface area in Park County. Of this, 30 percent are Herbman soils, 20 percent are Hiwan soils, and the remaining 50 percent are composed of rock outcrop and other minor soil units. The Herbman soils are found on mountain slopes and ridges, are shallow and well drained, and are derived mainly from igneous and metamorphic rocks. Hiwan soils are also found on mountain slopes and ridges, mainly facing north. They are shallow and well drained and are underlain by very gravelly sand. Weathered hard rock is at a depth of 12.7 to 51 cm (5 to 20 inches). The minor soil units associated with Herbman-Hiwan are rock outcrops on ridges and back slopes, Grimstone and Peiler soils on north-facing mountain slopes, Kitteredge and Troutdale soils on mountain slopes and in drainage ways, and Venerable soils on low terraces. These soils mainly support forestry, grazing, wildlife habitat, and recreation. They also could be used for community development. Within the mountain valleys, the soils underlying most wetlands are Cryoborol-Cryaquolls. This soil unit contains sandy-gravelly loam covered by a dense mat of partly decomposed vegetation. It is poorly to well drained with a moderate capacity to hold water (Price and Amen, 1984), which is advantageous for the drier months of the year.

### Wetland Types

Within the Rocky Mountain region, four major wetland types have been identified (Cooper, 1989):

1. **Riparian (riverine) Wetlands**--Found along moving water courses such as rivers and creeks, these wetlands receive a large seasonal pulse of water from the melting of mountain snowpacks. Flooding, sediment erosion, and deposition are characteristic. Riparian wetlands can be forested, such as the well-known Cottonwood Gallery Forest in the lowlands; shrub dominated, such as the willow thickets found along many streams; or dominated by herbaceous flowering plants, such as those along cascades in the mountains. Many riparian wetlands have saturated soils and/or high water tables only early in the growing season.

2. **High Mountain Wetlands**--These occur in regions that were glaciated during the Pleistocene Period. The glaciers have carved the mountains and deposited till (rocky material pushed ahead or to the side of glaciers, or left when a glacier melts out), creating landlords that slow the runoff of water. Wetlands are abundant and may occur behind glacial terminal moraines, where a valley is flat and streams meander; in kettle ponds within moraine deposits; and in areas where glaciers have impounded streams. Many high mountain wetlands have peat soils that are saturated for most of the growing season.

3. **Basin Wetlands**--Occurring in the level intermountain regions, these may be closed basins such as Great Salt Lake in Utah, where surface runoff from the mountains collects and no drainage occurs, or they may be smaller wetlands, such as those in the intermountain parks and basins of Colorado, Montana, and Wyoming. Many basin wetlands are saline or alkaline because of the chemical characteristics

of the solids transported into the basin by surface water. When the water evaporates, the saline or alkaline solids remain.

4. **Urban Wetlands**--In urban, commercial, and industrial areas, these wetlands are either created by runoff from hard surfaces or are fragments of naturally occurring wetlands that have been influenced by heavy loads of nutrients, pesticides, herbicides, metals, petroleum products, and other urban pollutants.

The wetlands affected by this project mitigation site are riverine wetlands.

In general, the wetlands of Park County, including the project and the mitigation sites, have been affected by mining, industrial, and agricultural activities. From mining activities, sediment loads were conveyed downstream and settled out in the slower-moving waters in the valley meadows. These sediments often altered the form and function of the impacted wetlands. In industrial cases, waste products resulting from the production of commercial products, such as charcoal, and ore processing, were deposited in wetlands.

Agricultural activities, such as grazing, contributed to surface and stream bank erosion. Cattle ate vegetation, exposing the soil to wind and water erosion. Trapping reduced the beaver population, which further reduced the biogenic stabilization of wetland complexes and stream channels. This reduction in beavers, coupled with cattle traversing the stream channel, resulted in the downcutting of meadows and terraces formed by beaver dams. This led to the direct loss of upstream wetlands and sediment deposition in downstream wetlands.

Although there are no statistics on wetland losses within Park County and the immediate vicinity of the project, Colorado ranks 21 out of 50 States in terms of the percent of wetlands lost. From 1780 to 1980, wetland losses in the State were estimated to be approximately 50 percent (Dahl, 1990). Wetland losses in Park County are likely far less than the statewide average because of the large undeveloped land area in the county. However, wetlands have been lost to water development (storage reservoirs) and mining activities, including peat mining (Cooper, 1990).

Low land use of Park County reflects the low population density. Seventy percent of the land is public, within national forest boundaries; 25 percent is used for ranching, and the remaining 4 to 5 percent is used for mining, industrial, and other uses. The public lands are used extensively for hiking, skiing, fishing, and other outdoor activities. Tourism is the principal industry of the county.

Park County, which is 5,610 square km (2,166 square miles), was established in 1861. By 1900, the population had reached approximately 3,000, with a population density of 0.39 persons per square km (1 person per square mile). By 1920, the population had dropped below 2,000, rose to 3,000 by 1940, fell by 1960 to below 2,000 again, and since then has steadily risen. Today the population is 7,200, or approximately 1.16 persons per square km (3 persons per square mile) (Exhibit 6-2). In contrast, Jefferson County, immediately to the east of Park County and west of Denver, has urbanized substantially from the 1950s to the 1990s. This county, in 1900, had a population of around 9,000. By 1950, the population had grown to close to 56,000, or 27.7 persons per square km (71 persons per square mile). From 1950 to 1990, the population of this urbanizing county grew to 438,000, or approximately 217.6 persons per square km (558 persons per square mile) (Exhibit 6-2).

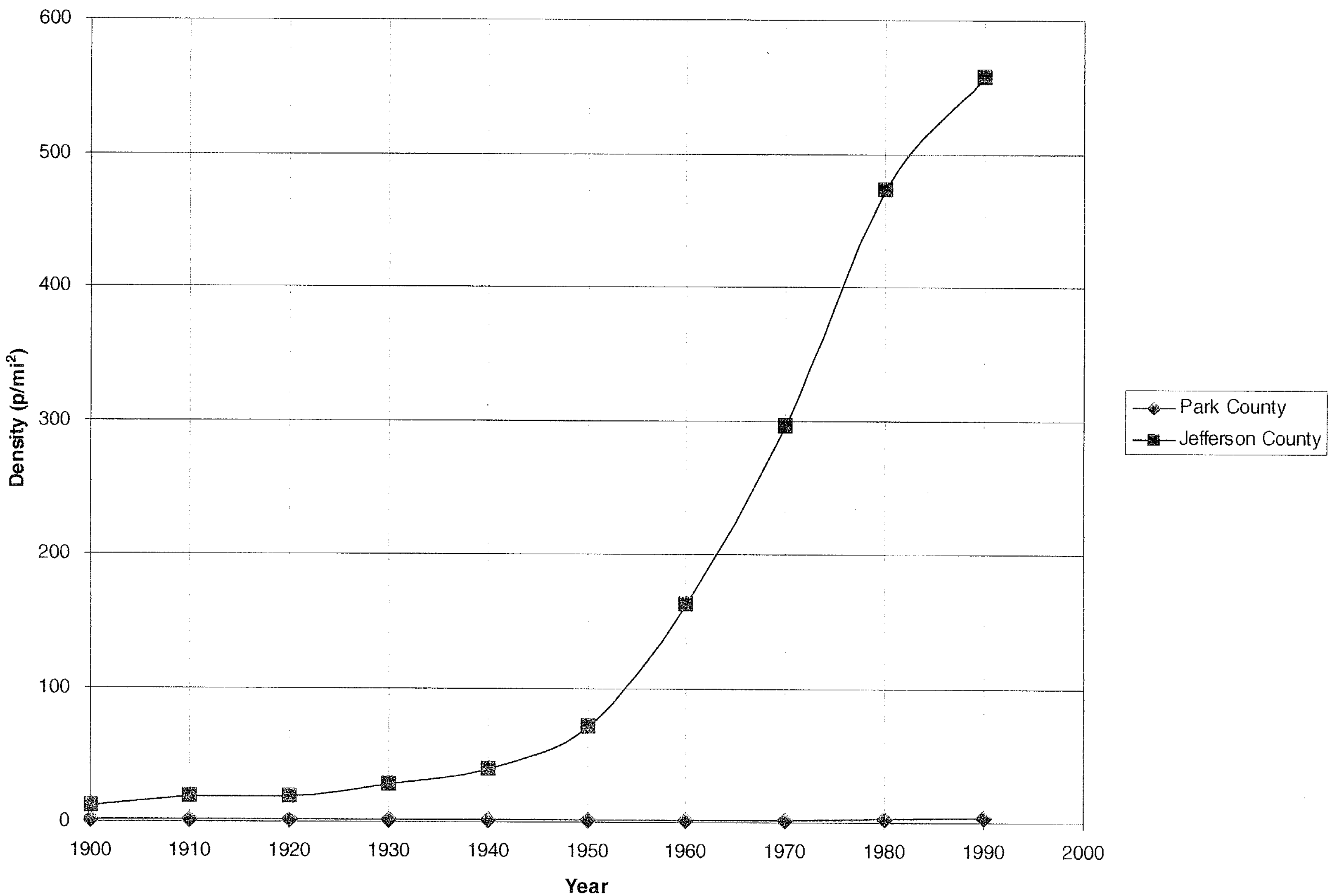



EXHIBIT 6-2:POPULATION DENSITIES OF PARK AND JEFFERSON COUNTIES, COLORADO

## THE PROJECT AND ITS WETLAND IMPACTS

The U.S. 285 highway construction project began immediately west of the small town of Grant, Colorado, and ended 4.67 km (2.9 miles) southeast of town. Over this distance, the elevation of the roadway descended with an average grade of -2.9 percent. The road improvements were intended to meet the current design standards of the American Association of State Highway & Transportation Officials (AASHTO), including traffic projections, for the subsequent 20 years. This involved adding a 3.05-m (10-foot wide) shoulder to each side of the highway, constructing the roadbed for two future lanes, and improving five horizontal curves (Exhibit 6-3).

For most of this stretch of highway, the northern side of the road is against the valley wall, with the southern side close to or bounded by the North Fork of the South Platte River. To avoid landslide hazards and associated safety issues, and after considering a number of alternatives, the CDOT and the FHWA concluded that it would be far safer to expand the roadway into the flood plain and streambed and move the stream channel south (Exhibit 6-4). To accomplish that task, approximately 1,250 m (4,100 feet) of stream channel had to be relocated, filling 0.97 ha (2.4 acres) of wetlands. The wetlands were predominantly shrub carr (characterized by woody shrubs, organic peat-soils, and an abundance of water), and riverine wetlands. They were moderate in quality, having been disturbed over the years by upstream mining and forestry and by road and railroad construction. An abandoned railroad bed lies on the southern edge of the North Fork flood plain across the stream from U.S. 285. The affected wetlands were dominated by mountain willow (*Salix monticola, Salix ligulifolia*), river birch (*Betula fontinalis*), bluejoint reed grass (*Calamagrostis canadensis*), and several species of sedge (*Carex* spp.).

## MITIGATION EFFORTS

Given the limited available nonwetland areas along the stream, the Department found it possible to mitigate only 0.20 ha (0.5 acres) of wetlands within the highway corridor. Consequently, only one-half acre of in-kind wetland mitigation was planned within the project corridor. The mitigation wetlands were to be shrub carr, dominated by willow.

The remaining 0.77 ha (1.9 acres) were mitigated outside of the highway corridor. The regulatory agencies made it clear that the off-site mitigation must be as close as possible to the sites of impact. After searching for a suitable site for more than a year, the FS came forward with a proposal to restore a wetland on their property. The location, within the Pike National Forest was along Hoosier Creek, which is about 1.61 km (1 mile) west of the start of the road improvements and approximately 0.80 km (0.5 mile) north of U.S. 285, on Park County Road 58 (Exhibit 6-5).

The Hoosier Creek mitigation site had been filled in the 1880s and 1890s, the area's forests had been logged to produce charcoal for smelters in the nearby mining camps and towns, such as Drake, Colorado (Hand and Angulski, 1988). Over 28 "beehive" brick kilns were built and operated to produce charcoal. Considerable waste byproducts from the kilns were deposited in riverine wetlands on the north side of Hoosier Creek for approximately 10 to 20 years before the site was abandoned (Exhibit 6-5). At the downstream, south end of the site, a railroad embankment was built and a trestle constructed over Hoosier Creek. The railroad was ultimately abandoned in the late 1930s and the structure over Hoosier Creek removed.

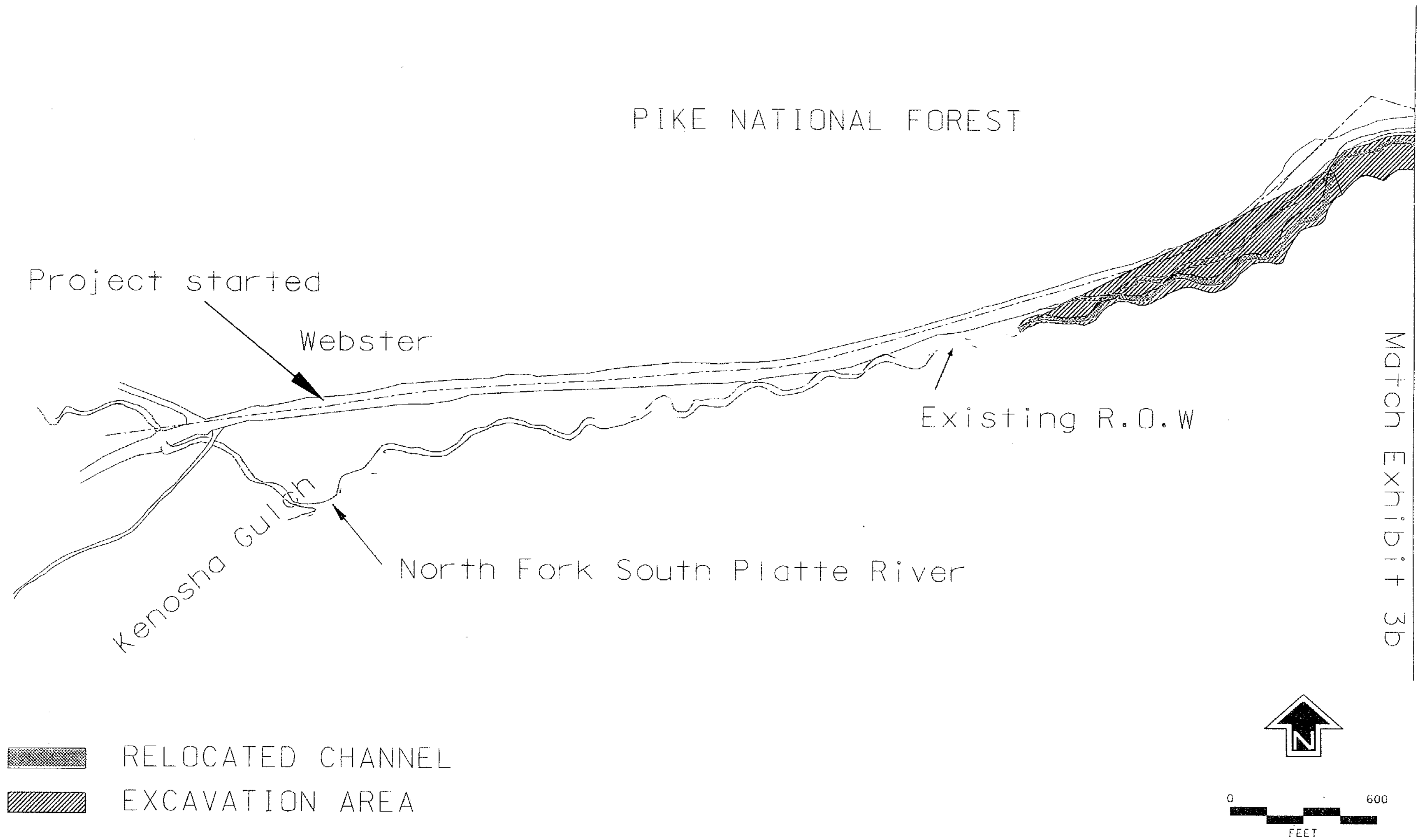



EXHIBIT 6-3a: ROAD ALIGNMENT

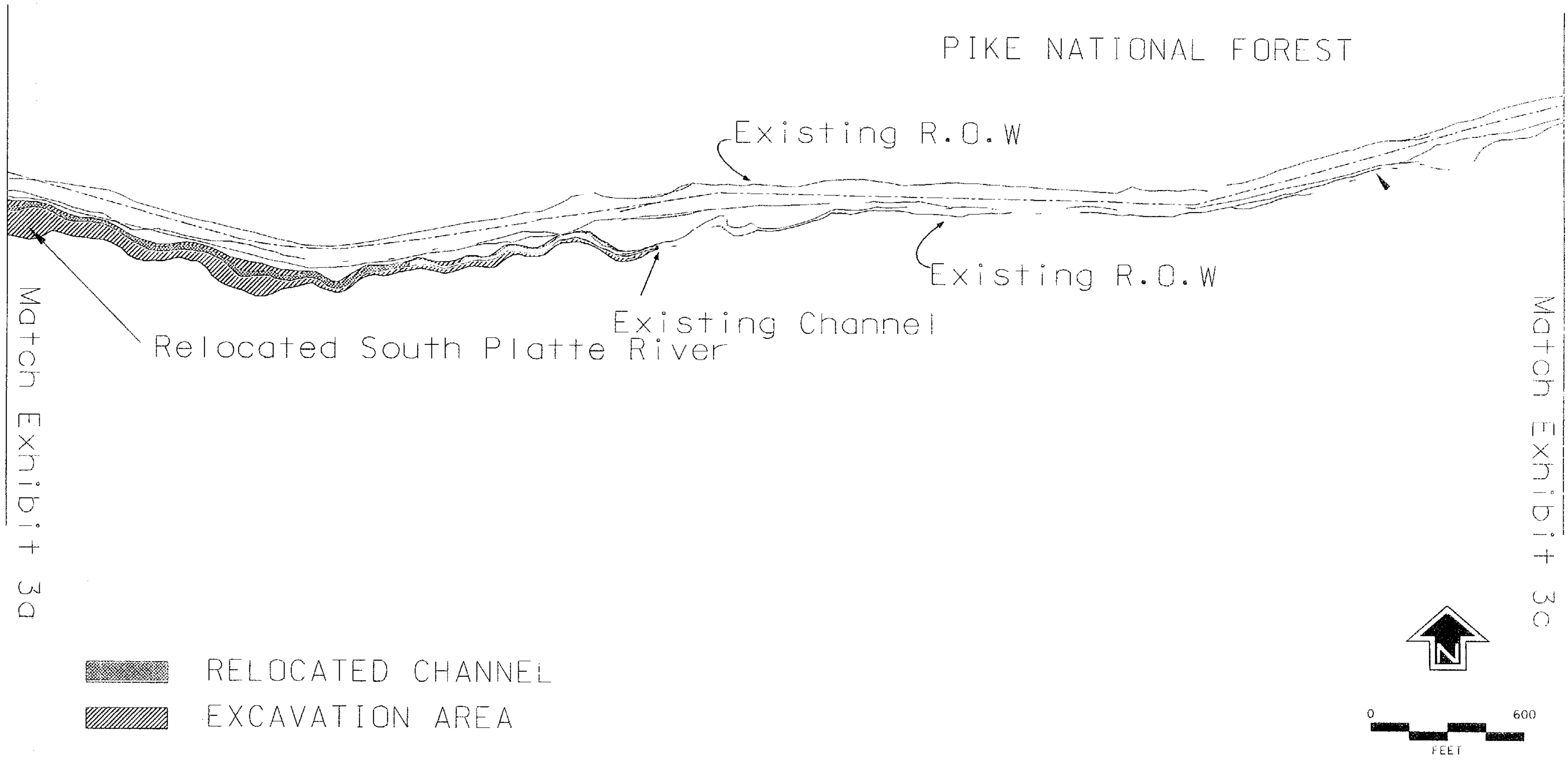



EXHIBIT 6-3b: ROAD ALIGNMENT

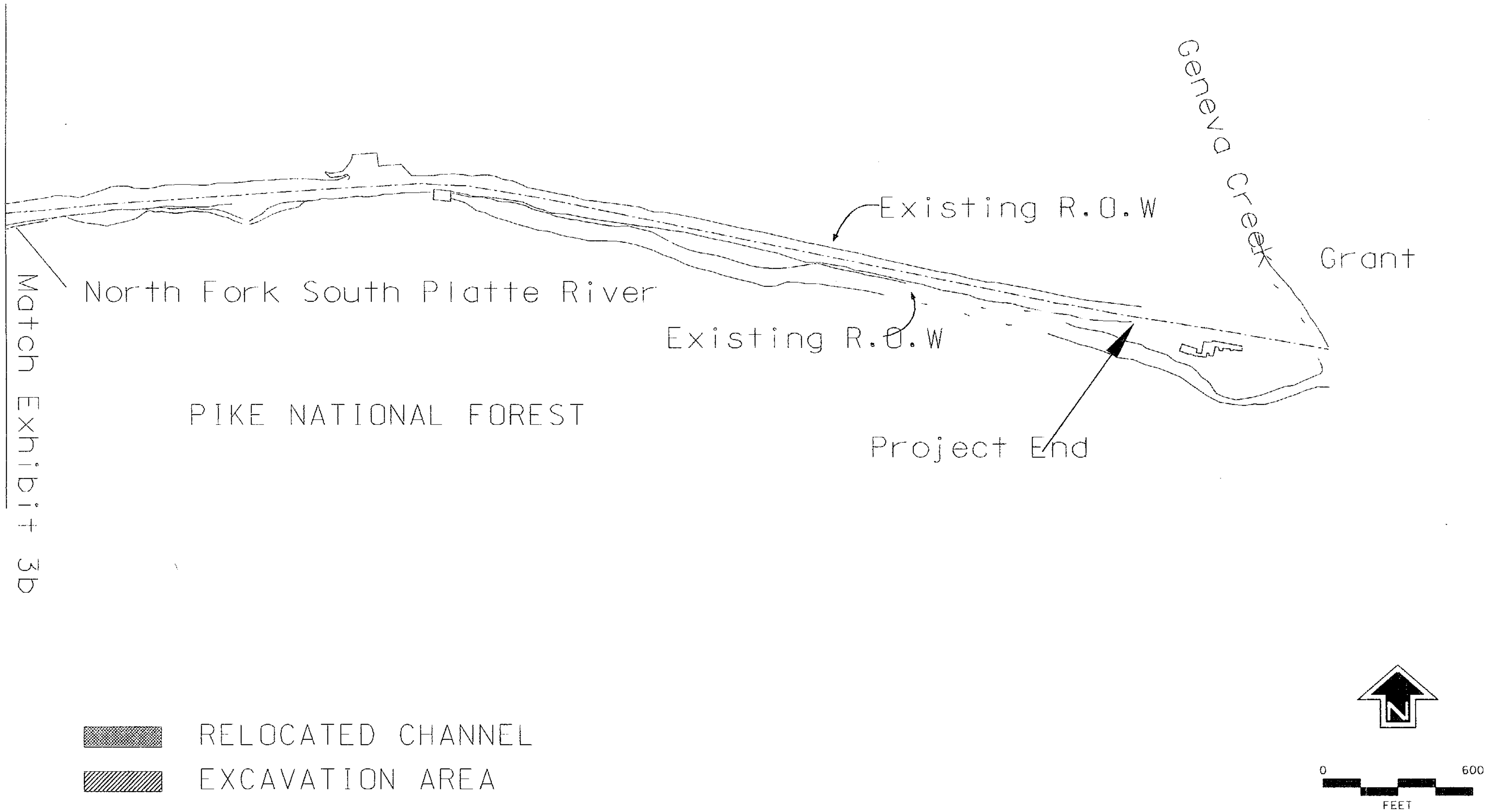
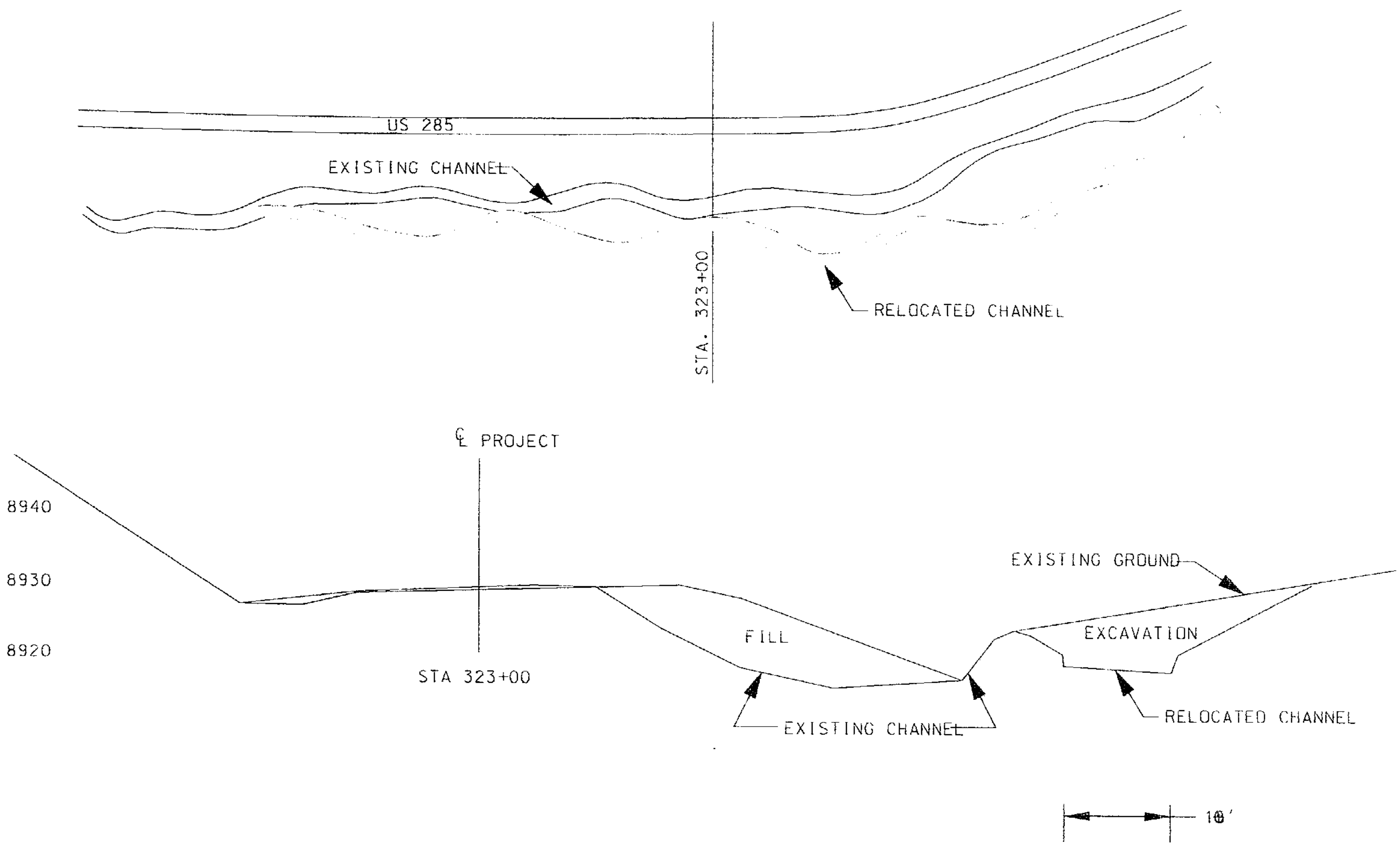



EXHIBIT 6-3c: ROAD ALIGNMENT




SCALE: 1" = 20'

NOTE: HYDRAULICS ORDINARY HIGH WATER IS 1.0' ABOVE BOTTOM OF RIVER.

PROJECT FR 285-4(23)
CRANT - N.E.
IN: NORTH FORK SOUTH PLATTE RIVER
NEAR: GRANT, PARK COUNTY, COLORADO
APPLICATION BY: COLORADO DEPT. OF HIGHWAYS
DATE: 7/31/87

EXHIBIT 6-4: ROAD CROSS-SECTION

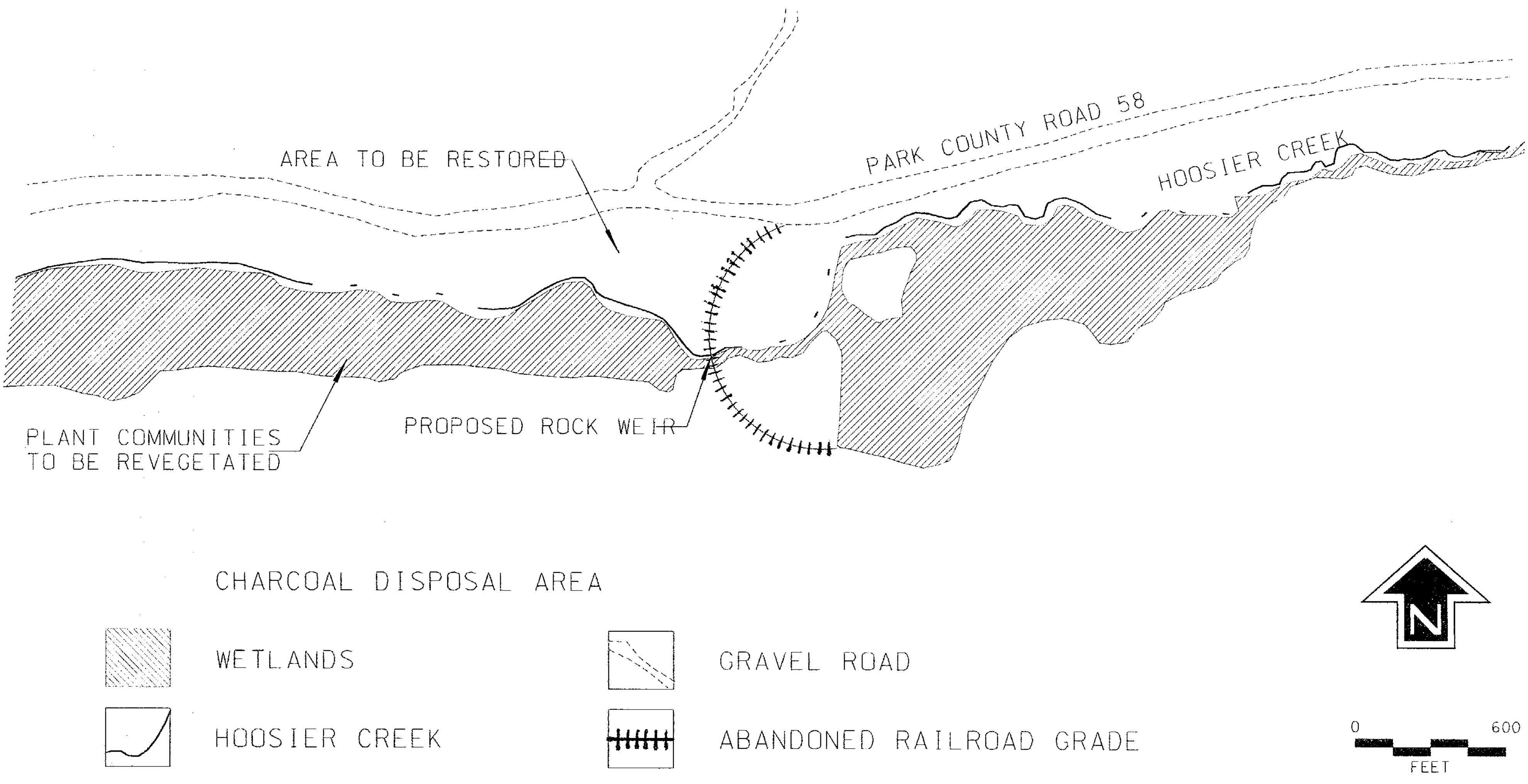



EXHIBIT 6-5: HOOSIER MITIGATION SITE

Subsequent to the charcoal operation, the site was heavily grazed by cattle permitted on the site by the FS, which contributed to the erosion of the stream channel. On the south side of Hoosier Creek, the flood plain was not filled or heavily damaged by grazing. Wetland plants survived on the peaty soils. With the expectation that the surviving plant communities could be re-created on the north side of Hoosier Creek, the FS proposed to the CDOT that the site be used for mitigation. After careful consideration by and discussion with the regulatory agencies, the Department proposed, in its Section 404 permit application to the COE, that the 0.81 ha (2 acres) of offsite mitigation be accomplished at this location.

The mitigation plan called for construction of a rock weir (Exhibit 6-6) at the abandoned railroad crossing at the east end of the site, which would raise the elevation of the water by 2.44 to 3.05 m (8 to 10 feet). The eroded channel above the control structure would be filled with excess angular rock obtained from the highway construction. Seven thousand six hundred and forty six (7,646) cubic m (ten thousand cubic yards) of charcoal waste along the north side of the creek was to be excavated and removed from the site. The material was transported to a nearby Boy Scout camp and used as the base for a parking lot. The charcoal was to be removed down to the peat, which was still present, as shown from exploratory borings. Willows were intended to be the dominant plant species used in the restoration. They were to be the anchor of the shrub carr community. The willow plantings were to be established by taking cuttings of nearby mature willows and inserting them 30.5 to 45.7 cm (12 to 18 inches) into the peat and adjacent soil.

The mitigation plan was not specific about the plant species, other than willow, that ultimately might be in the restored wetland. Nor was it specific about the density or diversity of plants. There were no goals or objectives or specific criteria established for the restoration work. No separate construction drawings or specifications were prepared or required by the permit application. These items were prepared for the onsite mitigation as part of the highway construction plans--plan drawings showed the location of the new stream bed and the placement of rock materials to control pools and riffles as well as the placement of vegetation along the new stream corridor. For the offsite mitigation, no hydrologic studies were conducted prior to developing the plan. As a result of public comments on the Section 404 permit, hydrologic data were collected along the stream corridor to support future mitigation planning for the wider U.S. 285 corridor. Only after the beginning of the restoration effort were groundwater wells installed at the Hoosier Creek site and plant lists developed.

## MITIGATION IMPLEMENTATION

Construction of the new stream corridor and onsite mitigation along the North Fork of the South Platte River proceeded concurrently with the construction of the road. The contractor was overseen by inspectors of the CDOT. Wetland soils were removed from the areas to be covered by the widened roadway and from the portion of the stream which was to be relocated, stockpiled for a short duration, and then respread in the flood plain of the reconstructed channel to help establish wetlands. Some materials such as boulders, cobbles, and topsoil that were not used for the onsite mitigation were stockpiled for use in the off-site area. Existing vegetation, including trees, was left along the new channel edge adjacent to the roadway to provide a buffer between the road and the new channel to minimize noise and visual impacts. The buffer vegetation, including plants from the seed bank, also would act as a filter for highway runoff. A drainage ditch was dug parallel to the highway to provide detention and sediment removal prior to discharge of runoff to the stream.

EXHIBIT 6-6: CONSTRUCTED ROCK WEIR IN ABANDONED RAILROAD EMBANKMENT
(PHOTOGRAPH BY KRISTINE MEIRING)

In October 1988, a restoration plan was prepared by Cooper (1988) for the Hoosier Creek mitigation site. In preparation of the plan, the proposed site was surveyed for the extent of wetlands and other resources that might be affected by the restoration work. The existing wetlands were mapped (Exhibit 6-5), but the COE did not require a Section 404 permit for the off-site mitigation itself, even though some of the existing wetlands were affected by the site grading and the rock weir was built in and across the stream channel.

The watershed tributary to the Hoosier Creek restoration is small but steep. It encompasses 7.5 square km (2.9 square miles) and falls from 3,200 m (10,500 feet) to 2,957 m (9,700 feet) msl. The average slope is 0.065.. The restoration site is located near the outlet of the watershed just upstream of its confluence with the North Fork. Prior to restoration, the slope of the stream was moderate to steep through the restoration site. Beaver had recently constructed dams upstream of the eroded channel section.

The west flood plain supported a sedge plant community, and the east flood plain contained the charcoal waste. The thickness and extent of the charcoal ash was determined in order to assess the amount of excavation necessary to expose the surface of the predisturbance peat soils. Five monitoring wells were installed to assess the groundwater across the buried soil formations. Based on the observed levels and the extent of peat, Cooper (1988) estimated the amount of wetland that could be restored. Cooper went on to speculate that:

> The charcoal ash in the Hoosier Creek Valley was placed onto willow carr wetlands. These wetlands most likely supported beavers and were quite complex in their hydrology and vegetation, just as the willow carr wetlands are in the upper part of Hoosier Creek Valley. The soil profile exposed by the degradation of Hoosier Creek into its flood plain shows the presence of peat deposits 125 - 150 cm (4 - 5 feet) thick beneath the charcoal ash. In the southern Rocky Mountains, peat this thick indicates a very long period of wetland stability, most likely many thousands of years. [Note: assumption of a peat deposition rate of 1 mm/year would result in an age estimate of approximately 1,500 years.]

Finally, Cooper estimated that there had originally been 2.73 ha (6.75 acres) of wetlands downstream of the railroad embankment (Exhibit 6-5) and 2.55 ha (6.3 acres) upstream. The wetlands covered by charcoal comprised 1.3 ha (3.2 acres). Besides the presence of peat, the groundwater regime indicated the appropriate hydrology for peat wetlands at the site. The groundwater was within 145 cm (57 inches) of the surface in July and 149 cm (58.7inches) in September.

## PLAN RECOMMENDATIONS

Two critical recommendations were set out in the restoration plan of Hoosier Creek: 1) remove the charcoal ash from the buried wetland surface, and 2) construct a hydraulic control structure across Hoosier Creek above the old railroad grade. The plan (Cooper, 1988) provided additional recommendations as follows:

3. The excavation work should be done in the late fall or early winter of 1988. Care should be taken not to run heavy equipment over the exposed peat surfaces. (This work was done in the winter when the peat was frozen and equipment could operate on the surface.)

4. Care should be taken to expose only the top peat surface and not remove any of the peat. The goal was to expose the soil surface that was buried under the charcoal.

5. Excavation should begin at the edge of Hoosier Creek and work back toward the upland edge. This would minimize compaction of the peat surface.

6. Hydraulic control structures should be built in the area west of the railroad grade to stop the degradation of Hoosier Creek and bring the water table in the peat areas adjacent to Hoosier Creek back up to the ground surface elevation.

7. Construction of a drop structure for each 30 to 45 cm (12 to 18 inches) of elevation upstream from the grade.

8. The first drop structure should be built just upstream from the railroad grade and should have a top elevation a few inches higher than the surrounding banks in the center of the creek. The structures should be keyed into the banks.

9. The first drop structure upstream of the weir should be the most durable and probably should be built of logs and rocks, but the construction specifications should be determined by the CDOT. Three or more structures may be necessary to stabilize the creek and bring the water table up to near the ground surface. The goal was to develop a valley system with a high water table located should be close to the ground surface for the early portion of the growing season in all areas. The water table could be allowed to drop 0.31 to 0.93 m (1 to 3 feet) below the soil surface in the later portion of the summers in many portions of the restoration area.

10. The peat surface should be planted with willow (*Salix* spp.) stem cuttings. These should be from dormant, living willows located in Hoosier Creek. Cuttings should be from a variety of shrubs in different parts of the valley so that many willow species will be introduced into the wetland restoration site. Cuttings should be taken while the willows are dormant, but before the ground in the mitigation site is frozen.

11. Cuttings at least 45 cm (18 inches) in length should be made at an acute angle, with sharp pruning shears, from the top of willow branches. These cuttings should be placed in a bucket of water to keep them moist during the cutting operation.

12. Willows should be planted in a density of approximately one stem per 0.93 square meters (10 square feet). The willows should not be planted in an evenly spaced pattern to resemble a grid, but should be planted in an irregular pattern to make a more natural and interesting site.

13. No other type of planting or seeding should be done.

The exclusive use of willows was proposed because of the difficulty of finding seeds or plant materials for other species found in subalpine wetland systems. Seed sources were not readily available when this project was undertaken. Further, it was believed that the other seeds would find their way into the restoration site by means of wind, water, wildlife, and rhizome migration from the extant, native wetland adjacent to the restored area. The seed bed in the exposed peat was expected to germinate. The plan also anticipated some activity by beavers: "Some beaver activity is natural to expect, but the removal of a large percentage of the planted willows could slow down the establishment of the wetland. If this occurs, it might be necessary to live trap one or more beavers from the area and transplant them to other areas" (Cooper, 1988).

The plan was quite simple and yet detailed in its implementation. After further site evaluation by the engineers of the CDOT, only one hydraulic structure was constructed--at the railroad grade. It was built from stone, and the original design was slightly modified a year later after icing problems developed on the downstream face of the structure. The structure changed the slope of the creek through the site from 0.06 to 0.02. The charcoal wastes, which were required to be excavated, were removed and hauled a short distance up the northern valley slope to construct a parking lot for a boy scout camp. Ultimately, the wastes were capped with local soils to prevent their movement down the slope.

The CDOT's site engineer, Mr. Ed Demming, took a personal interest in the restoration effort. Considering Cooper's recommendations and the stream's hydraulics, he carefully organized the construction procedures for the control structure at the railroad grade. He personally supervised the selection of materials and placement of stones to emulate a naturally occurring steep riffle. When construction work began in January 1988, he oversaw the backfilling of the eroded channel with rock and gravel, and the grading of the landscape following Cooper's plan.

After the spring thaw and runoff in May 1988, the willow cuttings were planted. Approximately 10,000 cuttings of several willow species were prepared, treated with Rootone (a commercial product intended to promote root development), and inserted into the newly exposed peat soil. Construction and planting were completed in the fall of 1989.

## MITIGATION RESULTS

In the following year, the results of the first growing season were evaluated. Photographs and video recordings were used to assess visually the early and late season conditions. Ten groundwater wells were established and water levels measured when vegetation surveys were conducted. In addition, eighteen 2 by 4-meter (6.6 by 13.2-foot) quadrant were established, (Exhibit 6-7) based on the following conditions:

1. Willow cutting enumeration
   a) Number of cuttings producing shoots
   b) Number of cuttings producing roots
   c) Number of shoots per stem
   d) Average shoot length
   e) Longest shoot length

2. Herbaceous vegetation
   a) Source (sod or seed)
   b) Ocular estimate of cover

**Results of the First Growing Season–May to July 1989** (Meiring et al., 1991):

- A majority of the willow cuttings planted in the 15 study plots produced both roots and shoots (98 percent and 86 percent , respectively) by July, 1989.

- The number of shoots per stem averaged from two on drier sites to 16 on wetter sites.

- The longest shoots approached 18 cm (7.1 inches) in length, averaging approximately 10 cm (3.9 inches) long.

In July, herbaceous species covered only a small portion of the study plot area. The annual willow herb (*Epilobium paniculatum*) was the most successful colonizing herbaceous species observed across the site.

July and August, 1989, had similar results:

- Root and shoot development occurred on 95 percent and 90 percent , respectively, of the willow cuttings which were monitored.

- The number of shoots per stem remained at five for the monitored cuttings.

- The average shoot length more than doubled over this 1-1/2 month period. The length of the longest shoot per cutting nearly tripled, on average.

- The longest shoot length recorded on the study plot was 61 cm (24 inches).

- Herbaceous species generally constituted less than 5 percent of the total cover in the study plots.

Species of willow herb and tufted hair grass (*Deschampsia caespitosa*) and sedges (*Carex* spp.) were the most common invaders of the early exposed surface during the first growing season.

By July of 1989, beaver had begun to construct dams through the restored wetland and along the new drainage course. These dams were expanded by August. One relatively large pool and two smaller ones were evident on the site. Also, signs of elk were observed in the restoration area despite a perimeter fence, which was intended to keep cattle out. The elk had browsed on the new willow shoots and had pulled a few cuttings completely out of the peat substrate.

After the 1989 growing season and based on the available information, the COE approved the mitigation as it existed. The COE's official record notes that the complete scope of the work was in compliance with the permit, that all the standard and special conditions had been met, that planting had been completed at the Hoosier Creek site, and that relocation of the North Fork was complete. This approval by the COE, however, did not stop the monitoring program on the Hoosier Creek restoration site. The CDOT continued for an additional 2 years (1990 and 1991).

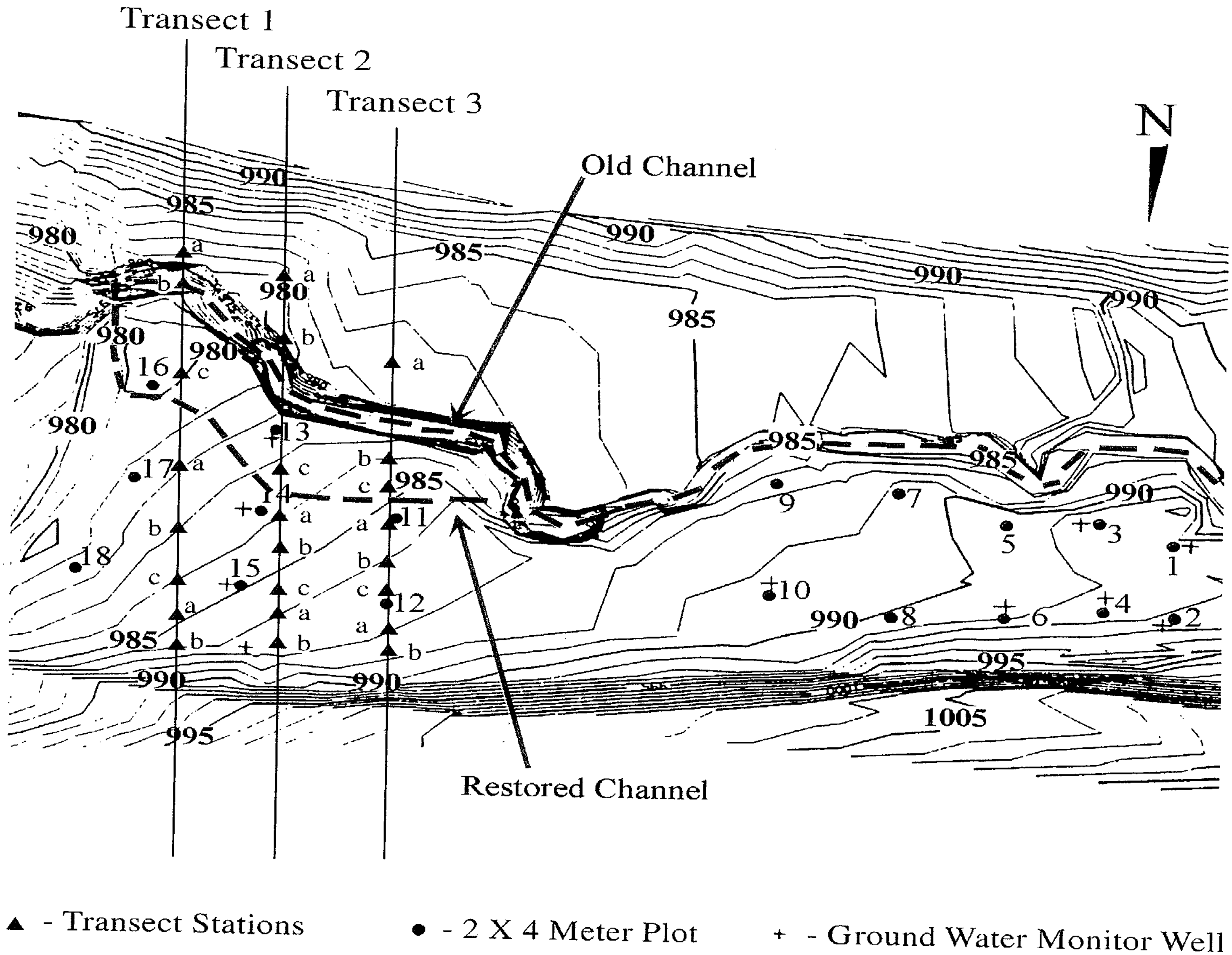



EXHIBIT 6-7: PLANT SAMPLING PLOTS (1990) AND TRANSECTS (1991) AND GROUNDWATER MONITORING WELLS (VAN LOH, 1991)

## Second Year Growth Observations–1990

The 1990 monitoring report (Von Loh, 1990) made a number of observations germane to the long-term success of the newly formed landscape. In general, the site was affected by several factors, including the following:

- A prolonged drought at the beginning of the growing season in June 1990
- Subsequent abnormally wet conditions in July and August
- Additional dam building activity by beaver
- Browsing of willow shoots by elk

Drought conditions during the onset of the growing season affected some willow cuttings along the upper, drier margins of the wetlands and adjacent mineral, upland soils. In the driest areas, which were considered marginal for willow establishment, a majority of the cuttings died. The depth of groundwater at these sites, measured in late August, was 2.5 to 46 cm (1 to 18 inches). At slightly lower elevations on the site, where late August groundwater levels of 20 to 25 cm (8 to 10 inches) were recorded, the shoots on willow cuttings established during the 1989 growing season were dead, but the cuttings had resprouted from the base. Some of these new sprouts exceeded 15 cm (5.9 inches) in length, as observed informally during the monitoring visit. The mortality among willow cuttings was the result of inundation and persistently high groundwater. This mortality was evident within and adjacent to the large beaver pond, west of the pond, in the main channel area; and east near the old railroad grade where pond water was present. Groundwater was either at or above the surface in these areas or within 5 cm (2 inches) of the surface in late August. Some willow cuttings had been incorporated into the beaver dam and resprouted there. Undoubtedly, a few cuttings were also used as food by beavers.

As expected, the contribution of herbaceous species to the plant cover increased significantly over the second growing season. Although only a trace of herbaceous cover was noted in 1989, an average of approximately 30 percent cover was reported in the established plots in 1990. The range of cover values varied from approximately 10 percent over non-wetland, mineral soils to approximately 60 percent on wetland soils dominated by tufted hair grass (*Deschampsia caespitosa*). Species diversity increased with an average of 12 herbaceous species present per plot and a range from 7 species occurring on mineral soils to as many as 20 species in the plot containing the exposed peat (Table 6-1).

Wind-blown seed appears to be the primary mechanism for colonization of these wetlands. Incidental pieces of sod left following the excavation of the charcoal residue were the next most important contributor of plant species. Undisturbed sedge communities along the south side of the excavation sent rhizomes as much as 1.5 m (4.5 feet) into the reclaimed area. In a similar manner, a stoloniferous cinquefoil (*Potentilla* spp.) was quite successful in colonizing the site (Meiring et al., 1990). Ponded areas supported buttercup (*Ranunculus hyperboreus*) in the more shallow waters. This species and *Ranunculus cymbalaria*, which grows on muddy areas adjacent to shore lines, formed a nearly solid mat.

After the second growing season, almost 60 percent of the willow cuttings occurring in the study plots survived (Von Loh, 1990). The majority of the cuttings that did not survive succumbed to inundation. Shoot lengths were recorded, but these data appear to have less importance because, as the shoots branched out, they were browsed. The average shoot length increased by approximately 50 percent sitewide over the previous season 14.4 cm (5.7 inches) versus 21.8 cm (8.6 inches). The average length of the longest shoot remained about the same, whereas on some individual plots the average length of the longest shoot doubled during the second growing season. Although willows were surviving, the site was becoming more of a sedge meadow than shrub carr. Moreover, owing to the activities of beaver whose dams had imposed a pool and riffle hydrologic regime, a great deal more water stood on the site than had been anticipated.

Wildlife use increased. In addition to the elk and beaver, which extended the length of the primary dam, the site also supported nesting mallards and blue-winged teal. An unidentified shorebird also nested on site and was observed with five young. Other species, including mule deer and red-tailed hawks, foraged in and near the site. The ponded areas supported an abundance of macro invertebrates (Von Loh, 1991).

## Table 6-1: Relative Abundance of Restored Species on Study Plots

1 = Rare 3 = Common 5 = Abundant

| Plant Species | Growth Form | Relative Abundance |
|---|---|---|
| *Agropyron sp.* | Grass | 3 |
| *Alopecurus aequalis* | Grass | 2 |
| *Deschampsia caespitosa* | Grass | 5 |
| *Festuca arizonica* | Grass | 2 |
| *Lycurus phleoides* | Grass | 2 |
| *Poa sp.* | Grass | 4 |
| | | |
| *Carex utriculata* | Sedge | 1 |
| *Carex sp.* | Sedge | 3 |
| *Juncus arcticus* | Rush | 4 |
| | | |
| *Artemisia frigida* | Subshrub | 1 |
| *Pentaphylloides floribunda* | Shrub | 3 |
| | | |
| *Achillea millefolium* | Forb | 2 |
| *Antennaria rosea* | Forb | 2 |
| *Aster sp.* | Forb | 1 |
| | | |
| *Capsella bursa-pastoris* | Forb | 1 |
| *Caryophyllaceae* | Forb | 1 |
| *Chenopodium sp.* | Forb | 2 |
| *Cirsium sp.* | Forb | 2 |
| *Corydalis aurea* | Forb | 1 |
| *Cruciferae* | Forb | 1 |
| | | |
| *Descurainea sophia* | Forb | 1 |
| *Draba sp.* | Forb | 2 |
| *Epilobium paniculatum* | Forb | 5 |
| *Epilobium sp.* | Forb | 5 |
| *Heterotheca sp.* | Forb | 1 |
| | | |
| *Lematagnoium rotatum* | Forb | 1 |
| *Lepidium densiflorum* | Forb | 1 |
| *Mimulus sp.* | Forb | 1 |
| *Penstemon sp.* | Forb | 1 |
| *Polemonium sp.* | Forb | 1 |
| *Polygonum aviculare* | Forb | 5 |
| *Potentilla sp. (stolon)* | Forb | 4 |
| *Potentilla sp.* | Forb | 3 |
| *Prunella neglecta* | Forb | 1 |
| | | |
| *Ranunculus cymbalaria* | Aquatic | 2 |
| *Ranunculus hyperboreus* | Aquatic | 4 |
| *Rumex sp.* | Forb | 2 |
| *Sedum lanceolatum* | Succulent | 1 |
| *Taraxacum officinale* | Forb | 2 |

**Third Growth Season–1991**

For assessing plant community development in the third year (1991), three transects oriented north to south were established across the floodplain and associated drainage ways (Exhibit 6-7). The data resulting from surveys along these transects were used to augment the data from the preceding 2 years. Along each transect, vegetation cover was estimated by species with 1 X 2-meter (3.3 by 6.6- foot) plots on alternating sides. In 1991, cover estimates were made for bryophytes in areas of open water within plots on peat, whereas bare ground and litter estimates were made for plots on mineral soils. The average cover values for vegetation along the three transects are:

Transect 1: (hair grass) 88 percent reclaimed and 108 percent undisturbed;

Transect 2: (sedge) 103 percent reclaimed and 80 percent undisturbed;

Transect 3: (willow) 89 percent reclaimed and 113 percent undisturbed (cover values exceed 100 percent due to multiple layers). The cover values obtained in 1991 for herbaceous species ranged between 64 percent and 110 percent , nearly double that observed in 1990 (Tables 6-2 to 6-4).

The more notable differences between the restored and existing plant communities along transect 1 included the dominance of shrubby cinquefoil and sedge in the existing communities. Seedlings of shrubby cinquefoil present in the restored portion will eventually contribute a greater amount of vegetation cover as they mature. Restored portions of Transect 2 remained saturated through the growing season, largely due to the influence of the beaver dam. As a result, species of sedge, by means of rhizomes, were spreading rapidly across this area. Portions of the transect were strongly influenced by the taller, more mature willow and bog birch shrubs, which shaded out much of the herbaceous cover that otherwise might have developed. The species composition was similar on both sides of Hoosier Creek on this transect.

A portion of the restored site lies upslope of the beaver ponds, which influence the groundwater table. The area is also fed by springs flowing under the road on the northern edge. Subsequently, the entire upper area was saturated year round. Growth from willow brush layer cuttings is most pronounced at this transect, averaging approximately 40 percent aerial cover in the reclaimed portion. Herbaceous species, particularly sedges, had done little colonizing on this transect, perhaps the result of fairly severe frost heaving, noted in the early part of the growing season.

Wildlife use through the final year of monitoring continued to increase sitewide, particularly waterfowl breeding and brood rearing. Elk continued to graze and browse across the enclosure but no longer pulled willow cuttings from the peat because the root systems were well developed. It appeared that a good population of brook trout was present in Hoosier Creek and in the ponds behind the beaver dam. There was an increase in the numbers of macro invertebrates that were observed, although no attempt was made to determine the species composition.

## Table 6-2: Reclaimed Wetlands North of Restored Hoosier Creek[a]

| Species | Transect 1 Quadrat[b]: a | b | c | | Transect 2 Quadrat[b]: a | b | c | | Transect 3 Quadrat[b]: a | b | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Carex aquatilis* | — | — | — | | 15 | 45 | 55 | | — | 10 | |
| *Carex rostrata* | 2 | 2 | — | | 15 | 20 | 10 | | — | — | |
| *Carex* sp. | — | 1 | 10 | | 5 | 5 | — | | — | — | |
| *Cirsium* sp. | 4 | — | — | | — | — | — | | — | — | |
| *Deschampsia caespitosa* | 8 | 20 | 35 | | 15 | 15 | 10 | | 15 | 10 | |
| *Epilobium* sp. | 15 | 1 | 2 | | 10 | 15 | 5 | | 15 | 8 | |
| *Hordeum brachyantherum* | — | 4 | 2 | | — | — | — | | 5 | 1 | |
| *Juncus arcticus* | 5 | 1 | 2 | | — | — | 3 | | 2 | — | |
| *Pentaphylloides floribunda* | 3 | — | — | | — | — | — | | — | — | |
| *Phleum alpinum* | 5 | 5 | 12 | | — | — | — | | 2 | 2 | |
| *Poa* sp. | 30 | 20 | 10 | | — | — | — | | — | 2 | |
| *Potentilla* sp. | 15 | 5 | 10 | | 5 | 3 | 5 | | 2 | 6 | |
| *Salix* sp. | — | 2 | 15 | | 5 | — | 8 | | 35 | 45 | |
| Unidentified forbs and grasses | 2 | 5 | 12 | | 11 | 3 | 5 | | 2 | 2 | |
| Bryophytes | — | — | — | Avg. | 15 | 3 | 2 | Avg. | 10 | 4 | Avg. |
| Total Cover | 89 | 66 | 110 | =88.3 | 96 | 109 | 103 | =102. | 88 | 90 | = 89 |
| Open Water | — | — | — | | 5 | — | 2 | 7 | — | — | |

*Source*: Von Loh, 1991.

[a]These wetlands are re-forming over peat saturated to the surface during the entire year along transects 2 and 3, but only during the spring along Transect 1.

[b]Quadrat size was 1 x 2 m.

## Table 6-3: Undisturbed Wetlands South of Restored Hoosier Creek[a]

| Species | Transect 1 | | | | Transect 2 | | | | Transect 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quadrat[b]: | a | b | c | | a | b | c | | a | b | c | |
| *Achillea millefolium* | — | — | — | | 2 | — | — | | — | — | — | |
| *Betula glandulosa* | — | — | — | | — | — | 10 | | — | — | — | |
| *Calamagrostis inexpansa* | — | — | — | | — | 5 | 3 | | — | — | — | |
| *Carex aquatilis* | 50 | 60 | 75 | | — | 50 | 10 | | 95 | 10 | 70 | |
| *Carex rostrata* | 20 | 5 | 2 | | 2 | 10 | 2 | | — | 65 | 15 | |
| *Carex* sp. | — | — | — | | — | 3 | — | | — | — | — | |
| *Deschampsia caespitosa* | 15 | 5 | 10 | | 15 | 15 | 10 | | 5 | 15 | 15 | |
| *Epilobium* sp. | — | — | — | | — | — | 5 | | 2 | 1 | 1 | |
| *Hordeum brachyantherum* | — | 2 | 4 | | 3 | — | — | | — | — | — | |
| *Juncus arcticus* | — | 5 | 8 | | 35 | — | — | | — | — | — | |
| *Pentaphylloides floribunda* | 1 | 30 | 15 | | — | 15 | 5 | | — | — | — | |
| *Potentilla* sp. | — | — | 2 | | 2 | — | — | | — | — | — | |
| *Salix planifolia* | 5 | 3 | — | | 3 | 5 | 30 | | — | — | 45 | |
| Unidentified forbs and grasses | 1 | 3 | 3 | Avg. | — | — | | Avg. | — | — | 2 | Avg. |
| Total Cover | 92 | 113 | 119 | = 108 | 62 | 103 | 75 | = 80 | 102 | 91 | 146 | = 113 |
| Open Water | 5 | — | — | | — | 20 | — | | — | 20 | 25 | |

*Source*: Von Loh, 1991.
[a]These wetlands are formed over peat saturated to the surface during the entire year.
[b]Quadrat size was 1 x 2 m.

## Table 6-4: Reclaimed Area on Mineral Soils, South of Reclaimed Channel

| | Transect 1 | | | Transect 2 | | | Transect 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Species — Quadrat: | a | b | | a | b | | a | b | |
| *Achillea millefolium* | — | — | | — | 1 | | — | — | |
| *Agrophyron* sp. | 10 | 2 | | 1 | 12 | | 20 | 10 | |
| *Antennaria* sp. | — | 3 | | — | — | | — | — | |
| *Artemisia frigida* | 4 | 5 | | — | — | | — | — | |
| *Chaenactis douglassii* | — | — | | — | — | | 5 | — | |
| *Cirsium* sp. | 2 | — | | 1 | — | | — | — | |
| *Epilobium* sp. | — | — | | 2 | 2 | | — | 2 | |
| *Festuca arizonica* | 5 | 5 | | 2 | 5 | | 1 | — | |
| *Hordeum brachyantherum* | 5 | — | | — | — | | — | — | |
| *Juncus arcticus* | 2 | 2 | | 1 | 1 | | — | — | |
| *Phleum alpinum* | — | — | | — | 2 | | | | |
| *Phacelia heterophylla* | — | 2 | | — | — | | — | — | |
| *Poa* sp. | — | 2 | | — | — | | 2 | 3 | |
| *Polygonum aviculare* | 2 | 1 | | — | — | | — | — | |
| *Potentilla* sp. | — | 4 | | — | 2 | | — | — | |
| Unidentified forbs and grasses | 2 | — | Avg. | 7 | 5 | Avg. | 2 | 3 | Avg. |
| Total Cover | 32 | 26 | 29 | 14 | 30 | 22 | 30 | 8 | 24 |
| Litter | 10 | 30 | | 5 | 20 | | 2 | 2 | |
| Bare ground | 58 | 44 | | 81 | 50 | | 68 | 80 | |

*Source*: Von Loh, 1991.

Beaver and elk use of the sites was not controlled. Beavers were allowed to develop dams and to forage around the resulting ponds. The relatively low fence surrounding the Hoosier creek mitigation site was easily crossed by elk, and they continued to browse freely on the revegetated area. No nonnative, invasive plant species appeared during the 3-year monitoring program. Moreover, because the hydraulic control structure on Hoosier Creek was fixed and could not be easily adjusted, water levels were not manipulated except by beaver. Consequently no management programs were employed.

The on-site mitigation of the North Platte River channel relocation was not as carefully monitored. The plantings appeared to suffer the same predation, but the results appeared, from casual inspection, to be satisfactory. This observation undoubtedly was shared by the project manager for the COE, for he ruled that the permit conditions had been met.

## CONCLUSIONS

The formulation, execution, and results of this mitigation effort were characterized by a good understanding of purpose and intent by the various participants, mainly the developing agency, the CDOT, and the regulators--the FWS and the COE. Although written documentation existed, the work proceeded, in large, on a "handshake" agreement. Many standard elements of a mitigation plan, such as the development of clear goals and the establishment of success criteria, were not articulated nor were construction drawings and specifications formulated for the Hoosier Creek offsite mitigation. In the end, representatives of the agencies involved in reviewing and approving the Section 404 permit agreed that both the onsite and offsite mitigation efforts were successful (Exhibit 6-10).

In addition, many of the agency representatives agreed that a large part of the success was attributable to the stewardship of Mr. Ed Demming with the CDOT. He not only took a great interest in the restoration, but also gave considerable time and thought to the process. And he was not alone in his efforts. Many others at the CDOT as well as with the regulatory agencies took a personal interest. The project manager for the COE visited the site on numerous occasions, closely following the restoration progress.

Dr. Cooper's restoration plan, as simple as it was, established the course of restoration. His reliance on nature's ability to "self-design" was one of the keys to success. With a minimum of plant introduction--save for the willow sprigs--the propagation of the site by a diverse, robust plant community was accomplished by natural forces: streamflow, wind, beaver, and other wildlife. The first step, however, was a hydrologic system put in place, as recommended by Dr. Cooper. Thus, having achieved suitable subsurface and surface water regimes, the natural biogenic forces--plants and animals--created a successful restoration project.

Once the charcoal deposits had been removed from the north side of the stream and hydrologic controls established, plants from the southern, existing wetland began to invade the newly created land form on the north side of the stream. Upstream of the constructed hydraulic control, beaver found suitable habitat to build a dam, which further modulated streamflow through the reach. The sustained flows and higher groundwater levels provided by the beaver dams undoubtedly favored the development of the sedge community. The beaver dams reduced the effects of high velocities and provided water during the drier periods of the year, which would not have been available in their absence, nor with the lower elevations of the downcut stream channel.

Although a reasonably extensive monitoring program was designed and executed, monitoring itself did not result in any regulatory agency intervention in the development of new habitat. Regulators and the implementing scientists seemed satisfied with the emerging results, including the sedge meadow and the diminished willow-carr. Consequently, there was no adaptive management other than minor repairs to the controlling rock weir.

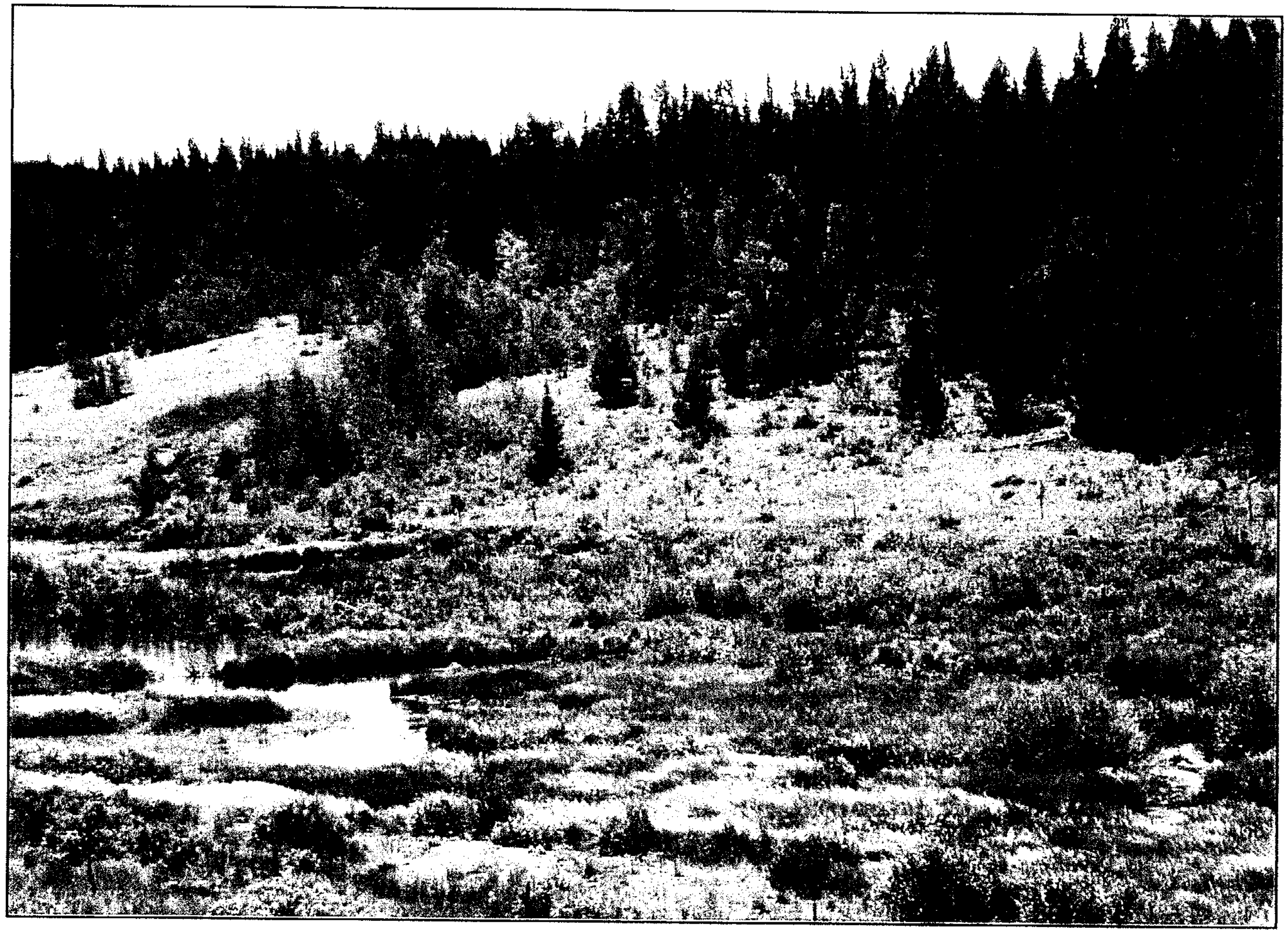


EXHIBIT 6-10: RESTORED SEDGE MEADOW WITH SHRUB CARR FRINGE (PHOTOGRAPH BY KRISTINE MEIRING)

## ACKNOWLEDGMENTS

The success of this project was directly related to the interest and commitment of the various participants. These participants ranged from the primary regulator, the COE, through the construction agency, the CDOT, to the scientific community, as represented by Dr. David Cooper, Research Scientist at Colorado State University, Fort Collins. Much of the material and insights to the project were provided to the authors by Ms. Kristine Meiring, wetlands biologist at CDOT. Ms. Meiring prepared the "Wetland Opinions," helped monitor the site, and shepherded the project along the trajectory to success. In addition, she documented the project's progress with photographs and videos and made public presentations. Mr. Ed Demming, the CDOT project engineer, was most responsible for the successful restoration of the hydrology at the Hoosier Creek site. He designed the control structure at the railroad embankment and the backfilling of the eroded channel. On a daily basis, he oversaw the construction of these restoration elements. Dr. Cooper developed the project concept. He also evaluated the site and recommended that it be used for mitigation; installed the first groundwater wells; and highlighted the importance of hydrology in the restoration effort. He also foresaw the role of beaver in the restoration results. Despite his intention that the site be more heavily vegetated by willow, he was determined to encourage the development of natural wetland features on the site, regardless of the species composition. Mr. Terry McKee, project engineer with the COE, took an extraordinary interest in the work and carefully monitored its progress. He was responsible for ultimately approving the end results. Mr. Bill Noonan, a biologist with the FWS Partners For Wildlife Program, and Mr. Jim Von Loh, also a botanist with the CDOT, both participated in field studies and in project review. Mr. Harold Warren, a resident of Grant, Colorado, provided an historical perspective.

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# CHAPTER 7

## KACHITULI OXBOW

This restoration project was established on the Sacramento River, in 1991, to compensate for wetlands losses caused by the development of a hotel, convention center, yacht basin, and other commercial construction totaling 113 hectares (ha) (280 acres) in Yolo County, California (Exhibit 7-1). State and Federal land--7.3 ha (18 acres)--were combined with several other developed parcels, including three existing marinas and a golf course to provide the convention center development site. Out of the 113 ha (280 acres), 10 percent were to remain as open space, discounting the golf course, which was to be remodeled.

The selected mitigation site was named Kachituli Oxbow, after a Native American village that once existed near the property (Kroeber, 1925). Environmental concerns about the project were based on several natural resource impacts:

1) Loss of riparian habitat
2) The loss of habitat for the Valley elderberry longhorn beetle (VELB) (*Desmocrous californicus dimorphus*), a federally listed threatened species.
3) Concern about State-listed species: Swainson's hawk (*Buteo swainsoni*), Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), and the Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*)
4) EPA concern over the loss of wetlands and shaded riverine habitat
5) Effects of the project on the water quality of the Sacramento River.

The U. S. Army Corps of Engineers (COE) had regulatory authority over the project under Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act, and was responsible for issuing the appropriate permits. In April 1985, the developer and Yolo County jointly submitted an application to the COE to fill wetlands and impact riparian habitat on the property. The Sacramento District of the COE concluded that: "...the proposed project may have a significant effect on the environment, and an Environmental Impact Report (EIR) is required" (COE, 1985). Public notice was issued in August 1985, requesting comments on the scope of the joint EIR/Environmental Impact Statement (EIS).

Conservation groups, including Defenders of Wildlife, Davis Audubon Society, American Fisheries Society, and The Sacramento River Preservation Trust, urged the COE to deny the Section 10 and Section 404 permits, based on habitat impacts. The Defenders of Wildlife (Spotts, 1986) pointed out that "The Sacramento River provides some of the best remaining riparian habitat in northern California, despite a reduction in habitat from an estimated 324,000 ha (800,000 acres) in 1848 to approximately 4,856 ha (12,000 acres) today." The conservation groups wrote numerous letters to Federal and State agencies, arguing for not selling the surplus lands to the county, denying the permits, or requiring that the developer set aside the riparian and elderberry savanna habitats.

The draft EIR/EIS was submitted in early September, 1986 (EDAW, Inc., 1986), and the public notice of the draft was issued later in the month. In this document, the proponents of the development project argued that Executive Order No. 11988, governing flood plains, and Executive Order 11990, protection of wetlands, had been satisfied. Responses to the opponents of the project were addressed in the final EIR/EIS (EDAW, Inc., 1986). A conceptual mitigation plan also was prepared as part of the process.


EXHIBIT 7-1: MAP OF CALIFORNIA

Anticipating that the COE would issue the permits, in November 1986, nine environmental groups jointly submitted guidelines for riparian habitat mitigation. These guidelines were ultimately used in forming the basis of the mitigation program.

On February 17, 1987, the District Engineer issued the combined permit, number 9051, allowing the project to proceed.

In December 1990, the developers requested that the mitigation requirements be reduced based on a redelineation of the area of riparian habitat and elderberry savanna to be impacted by the project. In the permit conditions, 59 ha (145 acres) of mitigation was required for the loss of riparian habitat and 19.4 ha (48 acres) was required for the loss of elderberry savanna. If revised, the new area for riparian habitat would have been approximately 45 ha (110 acres) and that for elderberry savanna habitat, 18.2 ha (45 acres). The COE denied the proposed change. A site for the riparian habitat was selected in 1990, and a plan was submitted to the COE for approval. The wetland portion of the mitigation plan was contained within the plan for riparian habitat.

## ENVIRONMENTAL AND SOCIAL SETTINGS

The proposed project--Lighthouse Marina--and the mitigation site are located near the city of Sacramento in Yolo County. The Sacramento River forms the northern boundary of the Lighthouse Marina project site, and the project's northeast corner lies at the confluence of the Sacramento and American Rivers. The mitigation site is 11.3 kilometers (km) (7 miles) upstream from West Sacramento on the west bank of the Sacramento River, in Yolo County.

Yolo County has a broad range of landscapes, varying from hilly to steep mountainous land in the California coastal ranges, to the broad, flat valley of the Sacramento River. The National Resources Conservation Service (formerly called the Soil Conservation Service, or SCS) estimates that two-thirds of the county's 2,678 square km (1,034 square miles) area is in the Sacramento Valley between the coastal ranges and the Sacramento River. The elevation difference between the valley and the coastal mountains is on the order of 610 meters (m) (2,000 feet (ft)). The valley floor, or the central part of Yolo County, starts at an elevation of 4.9 m (16 ft) at the southeastern edge and rises to 9.8 m (32 ft) at the northern boundary.

Yolo County lies within the great valley geophysical province (Andrews, 1972). This province includes the Sacramento and San Joaquin valleys and a small part of the coastal ranges, which are a series of mountains running parallel to the California coast. Yolo County consists of five separate geomorphic units. These are (1) flood plains and natural levees; (2) flood basins; (3) low alluvial plains, fans, and terraces; (4) low hills and dissected terraces; and (5) uplands of the coastal ranges. The project and mitigation site are located in flood plains and natural levees.

The climate is Mediterranean with warm, dry summers and cool, moist winters. The average daily temperature is approximately 62°F, with the average daily maximum being 76°F and the average daily minimum 49°F. There is a temperature gradient across the county from southwest to northeast that is influenced by air currents flowing eastward from the Pacific Ocean, with the cooler temperatures being near the ocean. The growing season is over 216 days long at a 50 percent probability. Approximately 55.9 centimeters (cm) (22 inches) of precipitation falls on the county--the majority as rainfall, less than 1 percent as snowfall. Approximately 90 percent of precipitation occurs during the months of November through April.

The surface water resources of the county depend on Cache Creek; Putah Creek; the Sacramento River; and the Glenn-Colusa Canal, which imports water from the Sierras and the southern Cascades. Based on the U.S. Geological Survey's Stream Gauging Station at Sacramento, the mean yield of the Sacramento River is 38.1 cm (15 inches). The yield, of course, is little influenced by the climatic conditions of the county in that the Sacramento River and its tributaries rise in the Sierras and a substantial portion of the runoff water is snowmelt. On the other hand, Cache Creek reflects Yolo County's hydrologic conditions. The yield of this stream is less than 7.6 cm (3 inches). Runoff is estimated at less than 14 percent of precipitation. Evaporation rates are high owing to the long, warm, dry periods of the year. Most crops are irrigated.

The soils of Yolo County comprise 12 associations, aggregated into 2 groups: alluvial fan or flood basin soils and upland and terrace soils. Seven of the associations belong to the first grouping and cover 63 percent of the county. The remaining five associations account for 37 percent of the county.

The first category contains: (1) Yolo-Brentwood, (2) Rincon-Marvin-Tehama, (3) Capay-Clear Lake, (4) Sycamore-Tyndall, (5) Sacramento, (6) Willows-Pescadero, and (7) Capay-Sacramento. These soils are considered to range from well-drained to poorly drained and are positioned on alluvial fans, basin rims and terraces, and in basins. This grouping, and in particular the Sycamore-Tyndall association, dominates both the project and mitigation sites. The other categories of associations are made up of soils that are excessively drained to well-drained. These associations include (1) Corning-Hillgate; (2) Sher-Horn-Balcom; (3) Dibble-Millsholm; (4) Positas; and (5) Glockwin.

Most of these soils are better drained today than in the past, owing to subsurface drainage and the control of flooding brought about by the extensive levee systems on the main stem of the Sacramento River and its tributaries. Also, large areas of native soils have been buried by the debris produced by hydraulic mining in the Sierra Nevada foothills (Andrews, 1972).

In particular, the Sycamore series of the Sycamore-Tyndall is found on flood plains and natural levees. Sycamore soils are silty and have existed long enough to accumulate some organic matter, giving them a darkened surface horizon (Andrews, 1972).

Four soil series exist on the project site: Lang sandy loam; Lang sandy loam, deep; Sycamore silt loam; and Tyndall very fine sandy loam. With the exception of Lang sandy loam, these soils are not considered hydric. In the case of Lang sandy loam, some soil components can be hydric; however, test pits excavated during the wetlands surveys did not find these hydric components present. Eighty percent of the Lang sandy loam lies in the area to the riverside of the levee. Only a small portion of the site in the southeast corner is underlain by Lang sandy loam.

The seasonal high groundwater for the area landward of the levee, based on an examination of soil character and standing groundwater levels, is 0.9 to 1.5 m (3 to 5 ft) below the land's surface. The soils, having been deposited by fluvial processes, are heterogeneous with strata of silt and clay. The primary sources of groundwater are the Sacramento River, which recharges the more permeable fine sand and silty clay lenses near the river, and upslope charging of aquifers from the western drainages. A primary source of water on the Kachituli site is infiltration and percolation of precipitation. Groundwater levels fluctuate with river levels.

The plant communities found on the project site conformed to the various man-made and natural landscapes. These landscapes include the levee, golf course, small residential developments, farmed fields, and remnant floodplain. Accordingly, the plant communities were identified and mapped (Exhibit 7-3) as follows:

- Annual grassland/forb
- Elderberry savanna (shrub/grass)
- Agricultural
- Riparian woodland containing the following distinct subcategories:
    - Upstream section
    - Middle section
    - Downstream section
- Young woodland and ditch woodland
- Oak woodland
- Horticultural

The largest plant communities were horticultural and annual grassland/forb, each making up 30 percent of the site with 24.3 ha (60 acres). Agricultural comprised 10.1 ha (25 acres). Riparian woodland, covering all five subcategories, made up approximately 10 percent of this site, or 6.1 ha (15 acres). The smallest areas were elderberry savanna with 4.0 ha (10 acres) (5 percent) and oak woodland with 1.2 ha (3 acres) (2 percent).

Prior to European settlement, the Sacramento River flowed between low, natural levees bordered by vast expanses of tule marshes. These marshes extended from the Sacramento-San Joaquin Islands to Colusa, California, a distance of 161 km (100 miles). Laterally, the marshes extended 3.2 to 4.8 km (2 to 3 miles). Tule lowlands and marshes blocked cross-valley travel. During the spring high water, oaks and cottonwoods standing on the natural levees were visible above the water surface. The water spread out across the marshes, extending for several kilometers on either side of the Sacramento River (Kelley, 1989). The tule marshes and riparian habitat were the dominant vegetation types. The natural levees bordering the river supported woody vegetation whereas the adjoining flood basins supported a variety of emergent vegetation.

These wetland vegetation forms were supported out to the 100-year flood limit (Katibah, 1984).

Settlers began to construct levees along the river and its tributaries in 1867. These man-made structures were replaced or built upon the natural levees and reduced the width of the river from kilometers to meters from the San Joaquin Delta to Colusa. As a result of the loss of tule marshes, along with wetland losses along other major rivers, California has the greatest percentage of wetland losses of any State since European settlement (Dahl, 1990). Today, in the vicinity of the project and including the project itself, levees enclose the Sacramento, Feather, and American Rivers.

By 1990, the population of Yolo County had reached 141,000 or 85 persons/square km (136 persons /square mile), six times what it was in 1940. By contrast, Sacramento County had a resident population of approximately 46,000 in 1900. By 1990, the population stood at over 1 million. The population density in SacramentoCounty is more than 625 persons/square km (1,000 persons/square mile), about 10 times that of Yolo County.

Today, the major industry of Yolo County is still agriculture, with related packing and canning industries. The principal field crops are sugar beets, alfalfa, rice, sorghum grain, barley, corn, wheat, and safflower. Tomatoes are an important export crop, as are almonds and fruits. More than 77 percent of the land in Yolo County is under agricultural use.

## THE PROJECT AND ITS WETLAND IMPACTS

The proposed development project was to be constructed on the west-bank low stream terrace and former floodplain of the Sacramento River. The topography is relatively flat, ranging in elevation between 4.6 to 6.1 m (15 and 20 ft) above mean sea level (msl). The highest point on the property is the top of the levee, at 12.2 m (40 ft) msl. Several borrow sites on the property extended below 4.6 m (15 ft) msl.

Throughout development of the project and the public debate, little attention was given to the wetlands impacts. The COE held Section 404 authority, but the main focus of the inter-agency discussions was the riparian and upland habitat associated with threatened and endangered Federal- and State-listed species. A wetland survey was conducted and the results became a part of the draft EIR/EIS (EDAW, Inc., 1986). Survey data were collected only on the river side of the levee in the Lang sandy loam soils (Exhibit 7-6), resulting in a mixed conclusion. Employing FWS wetlands criteria (Cowardin et al., 1979), the plant communities at the sample points indicated wetlands. Using the three parameter COE criteria set out in the 1985 delineation manual (COE, 1982), none of the sample points was classed as wetlands. None of the swales or the borrow pits on the landward side of the levee was investigated for wetland status.

The wetland boundaries were eventually defined by the COE, essentially by the "Record of Decision" for the Section 404 permit. The COE defined the wetlands on the project site as all those areas "lying below the 18-foot (5.5 m) elevation contour." This wetland definition was agreed to by all of the parties concerned. The wetlands so defined comprised 18.2 ha (45 acres). Although wetlands were fully mitigated, they were not the main focus of the controversy nor of the mitigation plan. The impacts to riparian habitat and the Valley Elderberry Longhorn Beetle (VELB) habitat drove the mitigation plan.

The Section 404 permit contained the following conditions:

- The permittee was to survey and clearly mark the 5.5 m (18-foot) elevation contour within the project boundaries. Project contractors were notified that no fill material was to be placed below the 5.5 m (18-foot) contour, other than that allowed within this permit for backfill and bank protection, without obtaining an additional COE permit. Upon completion of the above survey, the permittee was to notify the Sacramento District and allow the opportunity for inspection prior to construction. The permittee was to submit final project plans, which show the surveyed 5.5 m (18-foot) contour in relation to the project layout, to the District Engineer 30 days prior to construction (the area below the 18-foot contour was considered to be wetland).

The District Engineer determined that the impacts of the Lighthouse Marina project to the valuable riparian habitat on the water side of the Federal project levees was to be compensated. Thus the District Engineer required the permittee to acquire 58.7 ha (145 acres) of open space or agricultural land suitable for development and/or restoration of riparian habitat. This area was subject to the following conditions:

- The parcel was to be approved by the District Engineer and acquired 30 days prior to construction, or no more than 1 year after the issuance of this permit, whichever is first.

- If the land was acquired in more than one parcel, the parcels had to be contiguous or neighboring.

- All mitigation lands had to be located along the Sacramento River, and unless shown to be infeasible, in Yolo County.

- The total mitigation land(s) had to be dedicated in perpetuity for wildlife habitat through conditions, covenants, and restrictions (CC&Rs) recorded with the title to these lands. No improvements were to be made nor operations conducted in the mitigation lands whose purpose was not primarily to further the status of the land as wildlife habitat.

- The permittee had to monitor and maintain the restoration and/or developed habitat on the mitigation lands for 5 years following completion of the habitat development and/or restoration work....If at the end of five (5) years the habitat restoration and/or development was not fully successful, the permittee was to provide, as prescribed by the District Engineer, such additional reasonable and practical mitigation that is necessary to achieve the District Engineer's above-stated intent.

- The area of mitigation land could be reduced to a lesser amount if further analyses show such reduction to be appropriate following final design of the project. Any such analysis was to be done by the Sacramento District COE.

The Biological Assessment and Section 7 consultation report from the FWS on endangered species consultation was appended and made a part of the permit. It contained additional mitigation requirements, specifically for the threatened VELB.

Approximately a year after the permit was issued, proponents of the Lighthouse Marina project submitted a more detailed plan for meeting the special conditions of the permit. This plan consisted of two parts: endangered species compensation and off-site riparian mitigation. The loss of VELB habitat was estimated at 6.5 ha (16 acres). Given the required 3 to 1 mitigation ratio, mitigation was set at 19.5 ha (48 acres), as specified in the special conditions of the Section 404 permit. On the other hand, the riparian habitat losses were estimated to be 18.4 ha (45.4 acres), and the permit required the restoration of 58.7 ha (145 acres). The total mitigation was tentatively set at 78.1 ha (193 acres). The COE recognized, however, that these acreages were not the final numbers. They allowed the proponents of the project to resurvey the site and make necessary adjustments to the development plan and then return to the COE with the final numbers. This was done in a letter on December 18, 1990 (Corollo, 1990). In the letter, the area of riparian habitat mitigation was reduced to 43.7 ha (108 acres) and the VELB habitat was reduced to 16.4 ha (40.5 acres). Despite the proponents' analysis and arguments, the permit conditions remained the same: a total of 78.1 ha (193 acres) suitable for offsite mitigation split between riparian and VELB habitats. Within the geographic limits set out by the COE, a number of potential offsite mitigation sites were identified. These sites were surveyed for soils, plants, and the needed modifications to meet the mitigation conditions. No suitable parcels were found which could meet the entire mitigation requirement.

Project proponents petitioned the COE to divide the mitigation among an additional one or two mitigation sites. This was approved.

The main component of the mitigation plan involved the restoration, or creation, of riparian habitat. A suitable site was located 11.3 km (7 miles) upstream on the west bank of the Sacramento River (Exhibit 7-2). The 102.8 ha (254-acre) property was known as the Amen Ranch, and in recent years was used in the production of tomatoes (ECOS, 1989). The COE approved the property for off-site mitigation, although a considerable amount of excavation would be required. The portion of the Amen Ranch allowed as mitigation for the Lighthouse Marina project included 44.5 ha (110 acres) suitable for mitigation of riparian habitat, of which 40.5 ha (100 acres) were on the land side of the levee and 4.1 ha (10 acres) on the river side. This left 33.6 ha (83 acres) of mitigation to be found elsewhere.

Further upstream, a suitable location was found for the restoration of the VELB habitat. Additional off-site acreage was required and this was gained through acquisition and restoration of riparian habitat in one of the sites, known as the Mary Lake site, used to develop design criteria for off-site mitigation at the Amen Ranch property. Although creation and restoration work were carried out and monitored on the Amen Ranch and Mary Lake mitigation parcels, only the Amen Ranch mitigation site is discussed here, because this site was used for development of the Kachituli Oxbow wetland mitigation site and riparian habitat mitigation.

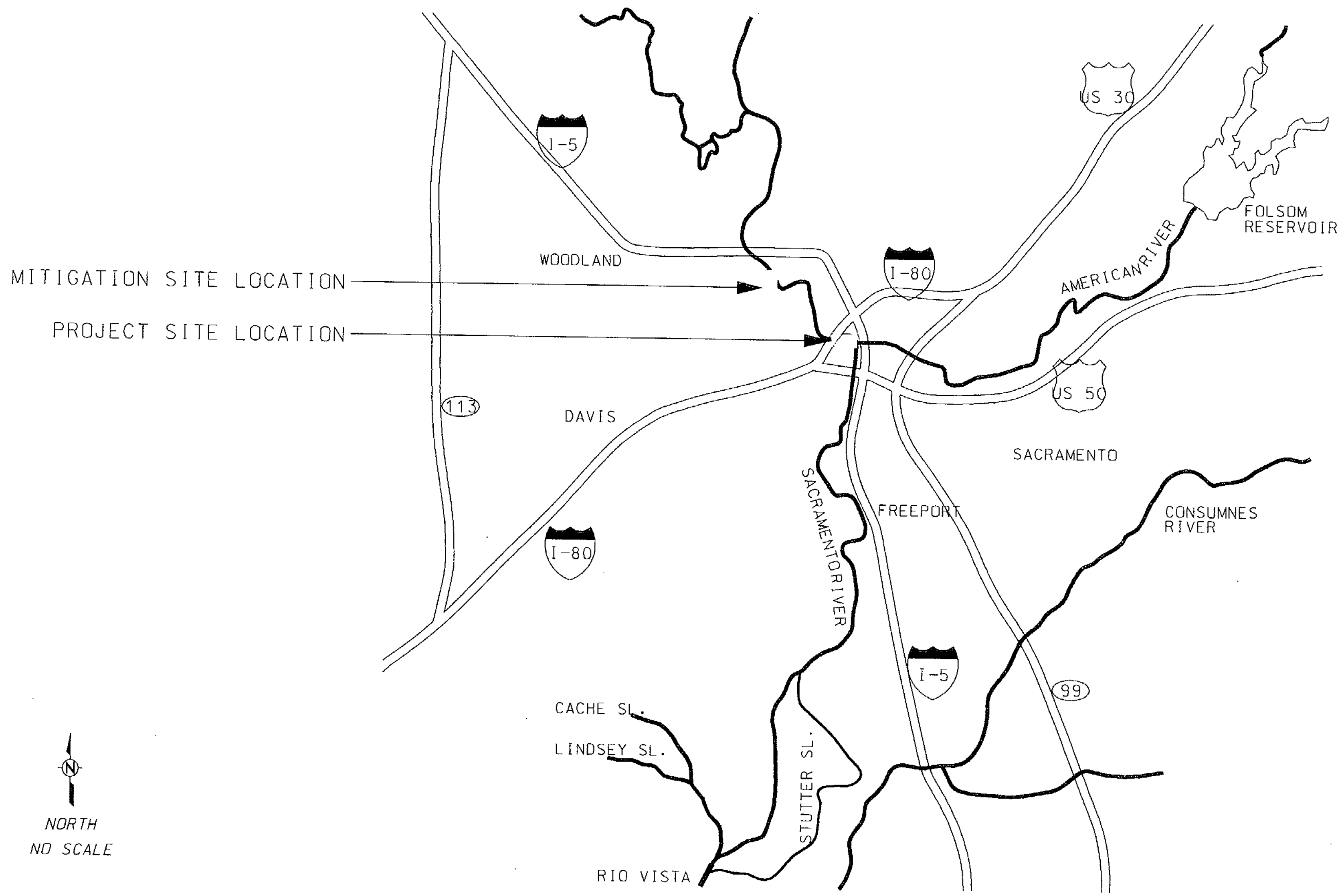


EXHIBIT 7-2: SACRAMENTO METROPOLITAN AREA

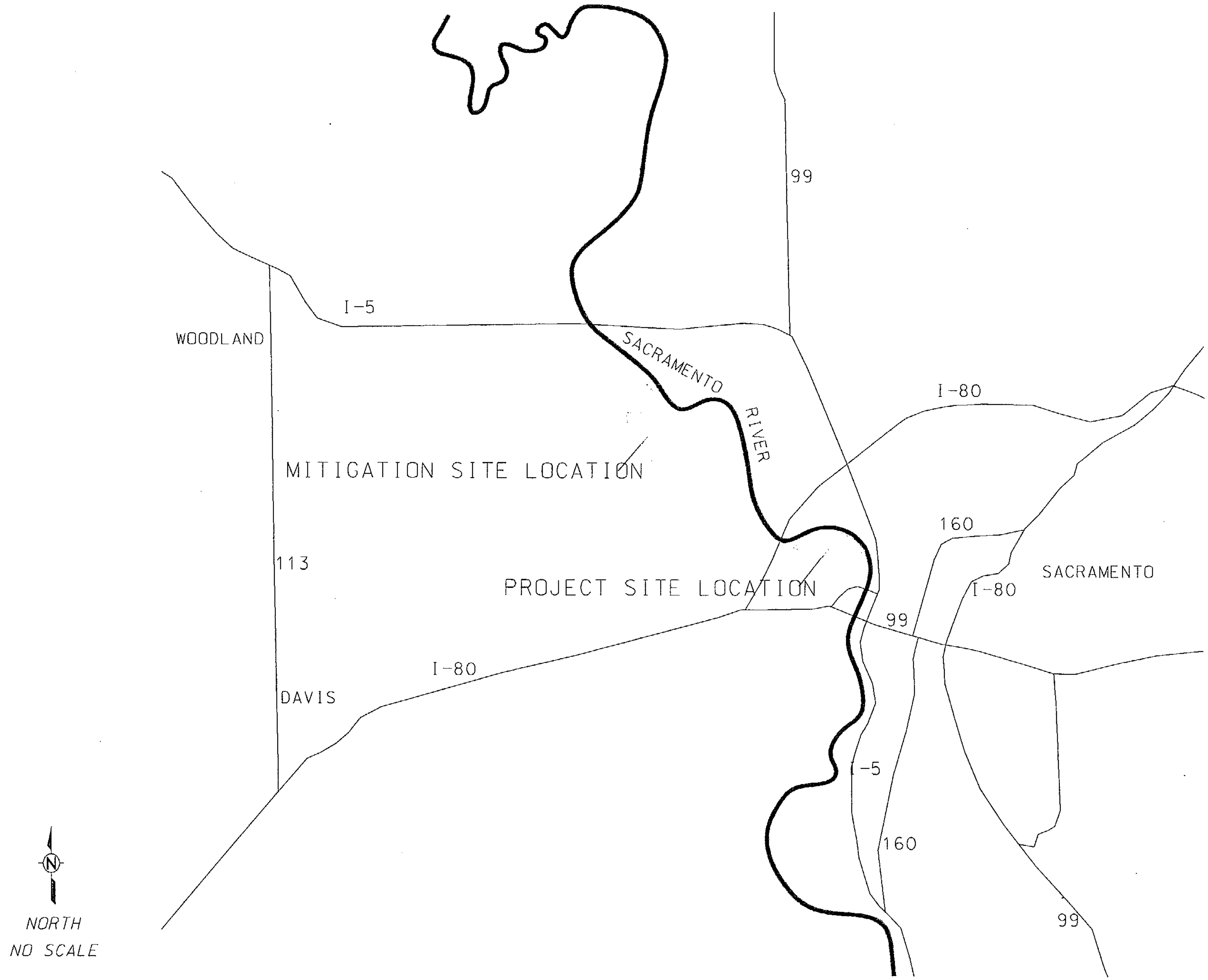


EXHIBIT 7-3: PROJECT SITE & MITIGATION SITE LOCATIONS

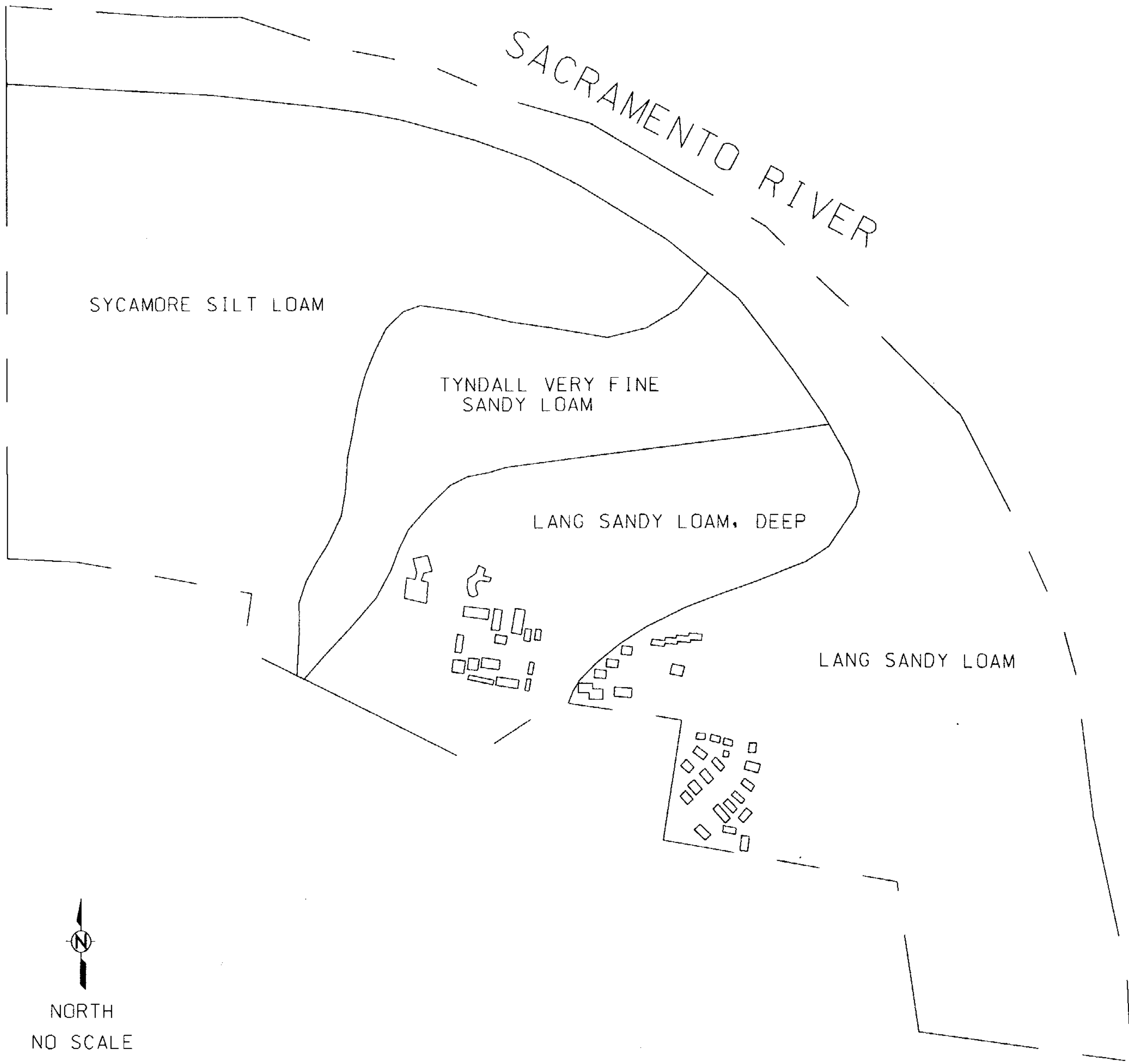


EXHIBIT 7-6: SOIL CLASSIFICATIONS OF THE PROJECT SITE

## THE MITIGATION SITE

The topography, soils, and hydrology of the development site and the Amen Ranch/Kachituli Oxbow mitigation site are similar. On the mitigation site, the topography is extremely flat, varying from 3.66 to 4.27 m (12 to 14 ft) msl. The surface soils are Sycamore silty clay loam and Sycamore complex, drained (Exhibit 7-7). The sources of water are precipitation, groundwater, and irrigation. The stratified soil layers, ranging from fine sands to clay, allow some lateral movement of groundwater. Soils of the river-side portion of the mitigation project (between the river and levees) are Valdez sandy loams. These soils are frequently flooded and support good riparian vegetation.

The Kachituli Oxbow site had been intensively farmed. Earlier, wheat and oats were grown, more recently, tomatoes were the main crop. A small walnut orchard remains on the site today. No prehistoric artifacts were found on the property (Cultural Resources Unlimited, 1990). Several agricultural buildings of more recent vintage remained. Most of these were removed with the exception of one large barn that was preserved for storage and may be considered for educational purposes in the future.

The design of the mitigation effort was divided into three phases: topographical, hydrologic, and botanical. The topographical characteristic of the mitigation site was to be that of a cutoff meander (oxbow lake or slough) of the Sacramento River (Exhibit 7-8). An assessment of soils on-site identified no old meander trenches. Several oxbow lakes near the site were examined and used as design reference sites. The oxbow meander was designed to have a bottom elevation of 5 fmsl, which is approximately 1.82 m (6 ft) above the invert elevation of the Sacramento River adjacent to the property but 0.91 m (3 ft) below the normal water elevation. The side slopes of the constructed meander in some cases approached 4 to 1 on the outside edge of the meander, but were much more shallow, 20 to 1, on the inside edge, as would have occurred naturally along the river. More than 191,140 cubic m (250,000 cubic yards) of earth had to be moved.

In this region of low, seasonally-distributed precipitation and given the absence of a surface water connection to the river, the hydrology for the mitigation site needed careful consideration. The depth to seasonal groundwater was measured across the site and the excavation specifications based on those depths. To ensure the establishment of the intended plant communities, an irrigation system was devised. This system operated with existing and new pumps using water rights associated with the former agricultural uses. The design called for irrigation to be terminated after the woody vegetation was established, that is, after their roots had reached adequate groundwater. One of the design objectives was to accomplish a self-sustaining landscape. The mitigation site might have become more quickly naturalized had it been possible to connect the meander to the Sacramento River. This would have required breaching the levee along the Sacramento River; an action that would be unacceptable to property owners protected by the levee as well as to the COE, who is responsible for its maintenance.

### DESIGN CRITERIA FOR THE MITIGATION SITE

Upstream of the Sacramento-San Joaquin Delta, the Sacramento Valley historically contained 222,585 ha (550,000 acres) of tule marshland (Kelley and Green, 1990), approximately 10 percent of the watershed area. Adjacent to the river, the natural levees supported lush riparian forests whereas behind the levees, in channels cut off by previous flood events, large shallow oxbow lakes existed. These characteristics were the ecological and geomorphic criteria for the design of the mitigation site. Field surveys were conducted on six oxbow lakes along the Sacramento and Feather Rivers to gather the characteristics for establishing the design criteria. The following collected information was used as the design criteria for the mitigation site:

- Depth, length, width, and bank slopes of the river channel in the meander area
- Presence of water on the channel floor
- General condition of the oxbow with regard to clearing and/or surrounding land uses and access routes
- Societal values and uses of the oxbow areas
- Soils
- Plant species and communities
- Ecological structure
- Hydrology

A sinuous meander channel was specified for the site with a 1.52 m (5-foot) deep pool of water at the southern end. This formed the deepest part of the excavation and measured 4.27 m (14 ft) from the existing land surface. The design elevations were supported by groundwater observations, which were made prior to plan development--groundwater was found to reach within 2.9 m (9.5 ft) of the existing soil surface (Kelley and Green, 1990). During excavation, the topsoil was saved and used for dressing the finished surface.

Water was intended to accumulate in the "low flow" channel and southern pool of the oxbow. These areas would provide habitat for emergent vegetation such as bulrush and cattail, and fish and waterfowl. On the outside curve of the oxbow, where the bank slopes were steeper, willows were to be planted on the toe of the cut, and box elder, buttonbush, and ash were to be planted on the bank slopes themselves (Exhibit 7-9). A cottonwood forest was designed for a 45.7 m (150-foot) strip at the top of the bank. Elderberry, valley oak, and box elder were to be interspersed among the cottonwoods. Further away from the oxbow, the design called for mixed elderberry savanna and oak woodland. A 0.81 ha (2-acre) sycamore grove was planned for the northwest corner of the site (Exhibit 7-8).

The inside portion of the oxbow was planted with willow at the toe, grading to ash and box elder. At the top of the bank a 45.7 m (150-foot) zone of mixed cottonwoods was planted. Adjacent to the cottonwood forest, a valley oak woodland and an elderberry savanna was planted in a strip 44.2 m (145 ft) wide and 427 m (1,400) ft long. A point bar was established on the inside of the oxbow. This bar had a very gentle slope, 40 to 1, providing habitat for such emergent vegetation as tule, rush, and sedge, as well as horsetail and various species of willows.

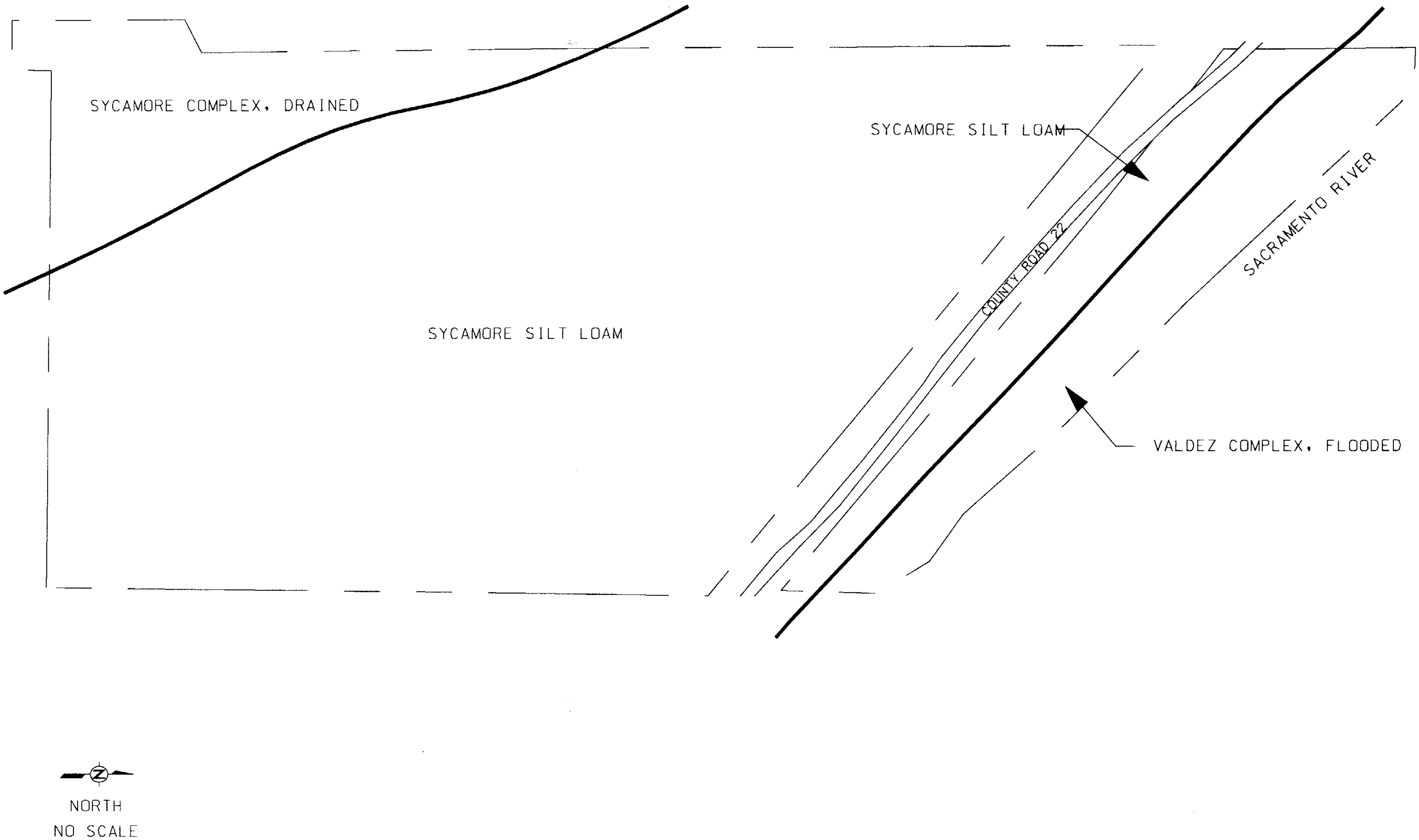


EXHIBIT 7-7: SOILS OF THE MITIGATION SITE

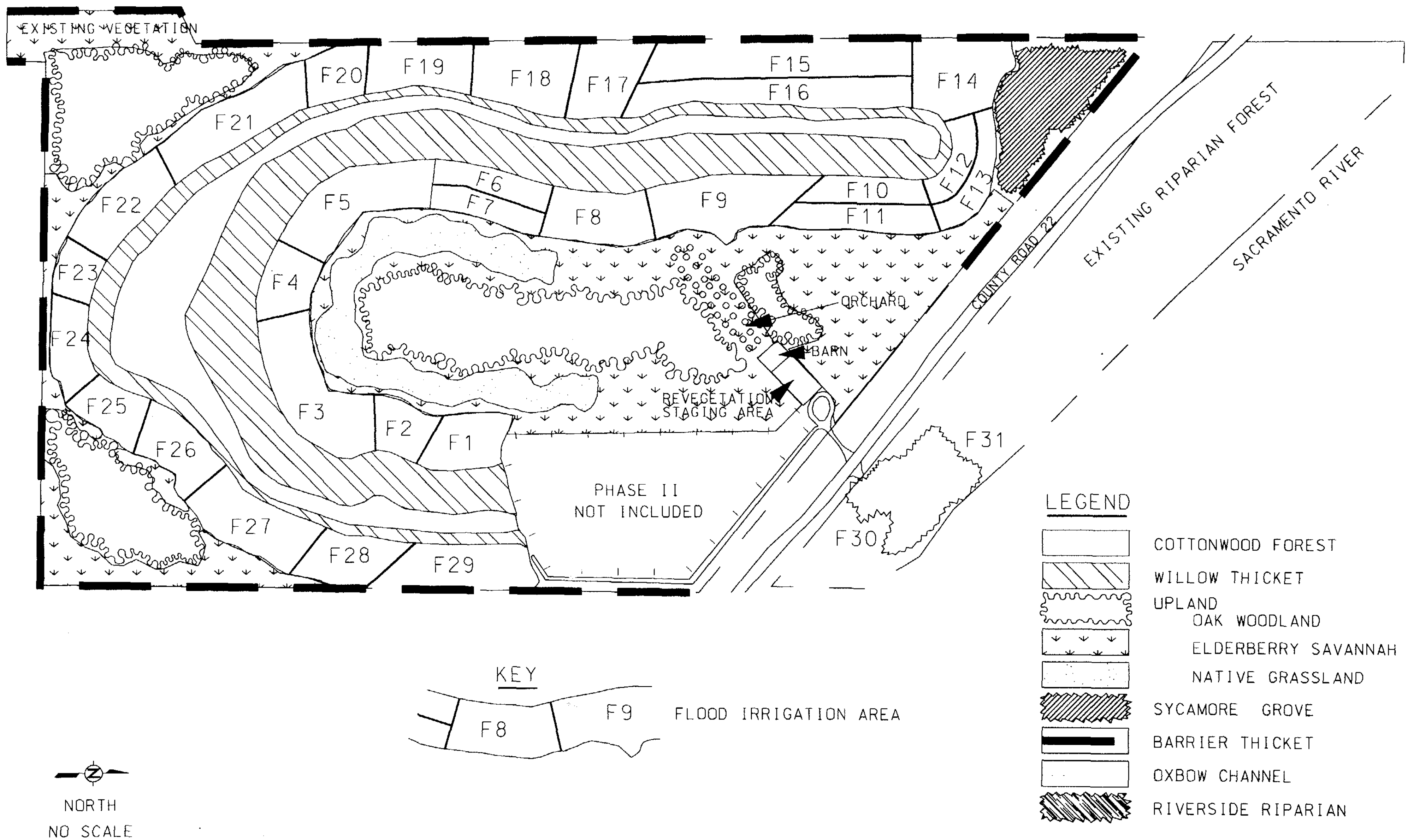


EXHIBIT 7-8: MITIGATION PLAN

EXHIBIT 7-9: WIDER PORTION OF THE OXBOW DURING THE DRY SEASON WITH HIGH WATER INDICATED BY DRIED ALGAE ON SHORE VEGETATION (PHOTOGRAPH BY DAVID KELLY)

The perimeter of the mitigation site was screened or buffered by planting a living fence consisting of blackberry and wild rose. Also, poison oak was considered for planting in subsequent years if it didn't establish on its own. This fence was intended to discourage people from walking onto the site from the surrounding agricultural areas. No public access was intended for the 5 years during which management and monitoring of the site was to take place, as required by the COE permit.

Some of the existing plant communities were left intact. For example, the domestic walnut grove was left to provide suitable perches, food, cover, and nesting habitat for a variety of birds, which would be attracted to the site. Also, the plan noted that native walnuts were interspersed throughout the riparian zone along the Sacramento River. Other native vegetation such as valley oak was flagged and saved if possible.

The plant communities and planting specifications were as follows (Miriam Green Associates, 1990):

> Oak Woodland--Approximately 5.67 ha (14 acres) of oak woodland were designated for the landward side of the levee. This area was planted predominantly with valley oak seedlings and acorns. Oaks were planted in mixed stands as the dominant species with other vegetation, including elderberry and California buckeye, especially at the edges. Oaks were planted on 12.2-m (40-foot) centers resulting in 61 trees per ha (25/acre), totaling 350 trees. Where direct seeding were employed, three acorns were placed in each hole. In cases where more than one seedling became established, the most robust seedling was left and the others removed. Elderberry and California buckeye (*Aesculus californica*) were planted as secondary species in the oak woodland at a density of 10 trees of each species per ha (4 per acre) resulting in 112 trees (56 of each elderberry and buckeye).
>
> Elderberry Savanna--One of the conditions of Permit No. 9051 was the incorporation of a minimum of 500 elderberry plants into the project design to compensate for the loss of endangered species habitat at the Lighthouse Marina project site. The required number of 500 were planted in an elderberry savanna; 921 elderberries shrubs were included in the entire project design. Elderberry will function as the dominant species on 8.5 ha (21 acres) of elderberry savanna habitat at a density of 61 plants per ha (25/acre) on 12.2-m (40-foot) centers, resulting in 525 elderberry plants in this zone. Valley oak was planted in the savanna at a density of 12.4 trees/ha (5 trees/ acre) resulting in 105 trees in 8.5 ha (21 acres) of habitat. California buckeye was planted at a density of 10 trees/ha (4 per acre) resulting in a total of 84 trees.
>
> Cottonwood Forest--The plan included 16.2 ha (40 acres) of cottonwood forest on the landward side of the levee. Cottonwoods will function as the dominant species, planted on 6.1-m (20-foot) centers, resulting in 267 trees per ha (108 trees per acre). A total of 4,320 cottonwood cuttings were planted.
>
> Valley oak, elderberry, box elder, and Oregon ash were planted as secondary species at various spacings in the cottonwood forest zone at densities of 5, 15, 20, and 20 per ha (2, 6, 8, and 8 per acre), respectively. This will result in a collective total of 960 trees in 16.2 ha (40 acres) (80, 240, 320, and 320 of each species, respectively).

Understory shrubs and fast-growing vines, such as poison oak and wild grape, were not planted during the first year. Not planting shrubs and vines in the first year facilitated easier maintenance and reduced competition with the desired tree species for light, nutrients, and water. These species were allowed to colonize the site naturally. Wild grape and poison oak had already colonized the landward side of the site where it had been left uncultivated.

Willow Thicket--The plan specified 6.1 ha (15 acres) of willow thicket. Four species of willows (red willow [*Salix laevigata*]), sandbar willow [*S. hindsiana*], Goodding's willow [*S. gooddingii* var. *variabilis*], and Arroyo willow [*S. lasiolepis*]) were planted as the primary vegetation type. Willows were planted on 3-meter (10-foot) centers resulting in 1,075 cuttings per ha (435/acre). A total of 6,525 cuttings were required. Box elder, Oregon ash, black walnut, and buttonbush were planted as secondary species at densities of 10, 10, 22, and 74 trees per ha (4, 4, 9, and 30 per acres), respectively, resulting in a collective total of 705 trees of these four species in the willow thicket.

Sycamore Grove--0.8 ha (2 acres) were designated as a sycamore grove on the land side of the levee proximate to the railroad tracks. This location was chosen because of the presence of good drainage characteristics of the soil and its suitability for sycamores. Several of the riparian areas studied have remnant stands of the California sycamore. Sycamores formerly were found scattered in riparian forests along the Sacramento River (Thompson, 1961; Holstein, 1984), but have become scarce except for disjunct stands somewhat removed from the densest riparian vegetation. Sycamore seedlings were contract grown in a nursery and served as the nucleus of the population. Sycamores were planted on 10.7 m (35-foot) centers resulting in 133 trees per ha (54 trees per acre). The 0.8 ha (2-acre) grove will support 108 trees at this density). Valley oak was planted on the edges of the sycamore grove on 15.2 m (50-foot) centers, resulting in 34 oaks scattered along the edges of the grove. Because parts of the irrigation scheme did not work properly, valley oak acorns were planted during the fall of 1991 at higher densities than specified.

Emergent Vegetation--Cattail, bulrush, and tule rhizomes were planted in the oxbow in the low flow channel and in the deep water pool on approximately 50-foot centers to promote the establishment of emergent vegetation in the wettest areas. Rootballs approximately 0.3 x 0.3 m (1 foot X 1 foot), including mud substrate, were planted into holes about the same size. Emergent vegetation was scattered along the irrigation ditches prior to construction; once common agricultural practices (such as the burning of vegetation along the channels) were discontinued, emergent species were expected to recolonize the bare areas.

Barrier Thicket--The barrier thicket or "living fence" covered about 1.82 ha (4.5 acres) around the perimeter of the mitigation site. Initially, only blackberry and wild rose were planted to establish the fence; other shrubs such as poison oak, coyote brush (*Baccharis pilularis*), and wild grape were expected to colonize this area later due to their presence in several locations on-site and nearby. Clumps of blackberry cuttings were be planted on 4.6-m (15-foot) centers along V-ditches resulting in an approximate total of 6,550 blackberry cuttings required for the living fence habitat zone. Clusters of nursery-grown wild rose seedlings were planted on 1.5-m (5-foot) centers, interspersed with the blackberries, resulting in 2,932 wild rose plants in this perimeter zone.

The success criteria for the Kachituli Oxbow mitigation project were based on planting densities for each habitat type (Table 7-1). The general criterion was 80 percent survival of each tree species (Table 7-2). No specific criteria were established for the establishment of understory cover or nonnative vegetation, nor for the percent cover to be achieved by the various other plantings and structured plant communities. The success criteria made no reference to the presence or absence of wildlife, but wildlife observations were included in the monitoring plan.

Management of the restoration process was primarily focused on irrigation of the newly installed plants. Water rights were associated with the property and these rights were to be exercised in providing adequate moisture for the establishment of the various plant communities ranging from those adapted to open water to those of upland character. Three methods of irrigation were employed: flood, sprinkler, and drip. It was anticipated that 3 years of irrigation would be necessary to establish the various plant communities. At the end of 3 years, if irrigation was still needed, it would be continued.

Flood irrigation was used in areas having reasonably flat slopes, between 0 and 2 percent. Using the existing pumping station on the Sacramento River, water was lifted to trenches that would then distribute the water throughout the designated irrigation area. Water was generally pumped during the dry season, from April through October.

Willow thickets were be irrigated with sprinklers. Again, it was anticipated that irrigation would be needed for the first 2 to 3 years, until the roots of these plants developed. Drip irrigation was intended for use in the oak woodland, elderberry savanna, and sycamore grove plantings. Water was applied to these areas from May through September.

One final concern of the project designers was that of predation by rodents, particularly mice. Plant collars and protective screens were designed and placed around seedlings. These collars also were intended to protect roots and help concentrate water into the root zone.

## MONITORING THE SITE

A 5-year monitoring program was required by the COE and specified in the special conditions attached to the permit. Aerial photographs were taken to document the changes in canopy cover. Trees were monitored for survival and growth. Aerial photographs taken in 1990, at the outset of the restoration process, served as a baseline for judging progress. At the end of the third year, the monitoring plan called for the regulatory agencies to review progress. This review was intended to permit adjustments to the management program to ensure the achievement of the 5-year goal. Both the planted species and those invading the site were be monitored in order to assess the maturation of the various plant communities. Although not identified as such, the review would meet the principle of adaptive management.

The monitoring program recognized the importance of wildlife to the intended landscape. A wildlife survey methodology was developed to include the following categories: birds, mammals, reptiles, and amphibians. Neither the anticipated species nor the sampling methodology were specified.

Finally, hydrologic monitoring was specified. This involved the installation of five water stage gages capable of measuring to the closest 0.03 m (0.1 foot). These gages were distributed along the oxbow. No groundwater monitoring was included at this point, although the deepest part of the oxbow would reflect local groundwater elevations, particularly during the dry months of the year, March through October. The measurements from the stage gages reflected the hydrologic effects of precipitation and local runoff, groundwater movement, and irrigation.

The final monitoring program was published in August, 1991 (Jones & Stokes Associates). The plan was assembled some 2-1/2 years after the permit was issued, and the plan anticipated further delays.

## MITIGATION IMPLEMENTATION AND RESULTS

In September, 1989, the COE allowed the proponents of the Lighthouse Marina project to proceed with clearing and grading activities on the project site. The final restoration plan was approved by the regulating agencies in October, 1990. Shortly thereafter, excavation of the oxbow began. Following excavation, planting was started in July, 1991.

### ☼ FIRST YEAR

At the end of the first year, 1992, a healthy cover crop of clover prevented weedy species from invading the site. Some desirable plant species such as sandbar willow were beginning to self-propagate. The majority of the plant materials survived, and the barrier thicket surrounding the restoration site prospered during the first year. In the riverside riparian areas, more than 95 percent of the plant material survived and was growing vigorously. In this area, weed propagation did not seem to be a problem at the end of the first year.

## Table 7-1: Cumulative Plant Totals

| Habitat Type and Species | Acreage | Density (plants/acre) | Approximate Spacing | Total No. of Plants | Type of Installation[a] |
|---|---|---|---|---|---|
| Oak woodland | 14 | | | | |
| Valley oak | | 24 | 40' on center (oc) | 350 | C, S |
| Elderberry | | 4 | Varies | 56 | C |
| California buckeye | | 4 | Varies single spec. | 56 | S |
| Sycamore grove | 2 | | | | |
| California sycamore | | 54 | 35 | 108 | C |
| Valley oak | | 17 | 50 | 34 | C, S |
| Elderberry savanna | 21 | | | | |
| Elderberry | | 25 | 40 | 525 | C |
| Valley oak | | 5 | Varies | 105 | C, S |
| California buckeye | | 4 | Varies | 84 | S |
| Cottonwood/oak riparian | 40 | | | | |
| Cottonwood | | 108 | 20' | 4,320 | P |
| Valley oak | | 2 | Varies | 80 | C |
| Box elder | | 8 | Varies | 320 | C |
| Elderberry | | 6 | Varies | 240 | C |
| Oregon ash | | 8 | Varies | 320 | C |
| Riverside riparian | 10 | | | | |
| Cottonwood | | 54 | 35 | 540 | X |
| Valley oak | | 2 | 100 | 20 | S |
| Elderberry | | 10 | Varies | 100 | C |
| Box elder | | 8 | Varies | 80 | C |
| Oregon ash | | 8 | Varies | 80 | C |
| California sycamore | | 54 | 35 | 54 | C |
| (1 acre only) | | 4 | Varies | 40 | C |
| Buttonbush | | | | | |
| Willow thicket | 15 | | | | |
| Willows (various | | 435 | 10 | 6,525 | P, X |
| spacing) | | 30 | Varies | 450 | C |
| Buttonbush | | 4 | Varies | 60 | C |
| Box elder | | 4· | Varies | 60 | C |
| Oregon ash | | 9 | Varies | 135 | S |
| California black | | | | | |
| walnut | | | | | |
| Barrier thickets | 4.5 | | | | |
| Blackberry | | Varies | 15' oc in v ditch row | 6,550 | X |
| Wild rose | | varies | 5' oc in v ditch row | 2,932 | C |
| Existing wetland area | 1.2 | | | | |
| Mud flat | 3.5 | | | | |
| Project Totals | 111.2 | Varies | Varies | 24,224 | |

*Source*: Miriam Green Associates, 1990
[a]Key: C = container, S = direct seeded, P = pole cutting, X = wattle or cutting

**Table 7-2: Five-year Success Criteria**

| Species | Initial Planting | 20 percent Loss | 80 percent Survival |
|---|---|---|---|
| Box elder | 140 | 92 | 368 |
| California buckeye | 140 | 28 | 112 |
| Buttonbush | 490 | 98 | 392 |
| Oregon ash | 460 | 92 | 368 |
| Black walnut | 135 | 27 | 108 |
| California sycamore | 162 | 32 | 130 |
| Cottonwood | 4,860 | 972 | 3,888 |
| Valley oak | 589 | 118 | 471 |
| Wild rose | 2,932 | 586 | 2,346 |
| Blackberry | 6,550 | 1,310 | 5,240 |
| Elderberry | 921 | 184 | 737 |
| Willow | 6,525 | 1,305 | 5,220 |
| Total no. plants | 24,224 | 4,845 | 19,379 |

*Source*: Miriam Green Associates, 1990

Dense weedy ground cover in the valley oak woodland made it very difficult to locate the oak seedlings. Based on those located, approximately 25 percent of the seeds had germinated and survived the first year–1992. All in all, the first year progress in establishing the intended plant communities seemed to be successful. Several recommendations were made: 1) manual or chemical removal of weeds around cottonwood and willow trees, 2) removal of cover crop duff around the perimeter of the trees, 3) periodic installation of replacement plants in the upland monitoring units to compensate for additional mortality, 4) installation of raptor perches to encourage rodent predation (rodents were destroying some of the woody plantings), and 5) irrigation of the valley oak seedlings during the dry season.

Only birds were monitored in the first year's wildlife monitoring report (Jones & Stokes Associates, 1992) submitted to the COE. A total of 43 bird species was observed during the winter and spring surveys. The bird populations were divided among the various habitat types. Eleven species were observed in the upland units, six species in the oxbow lake and nine species in the woodland habitats. A similar distribution was observed during the spring survey. A few mammals, or their signs, were reported: black-tailed hares, raccoons, and California blacktail deer.

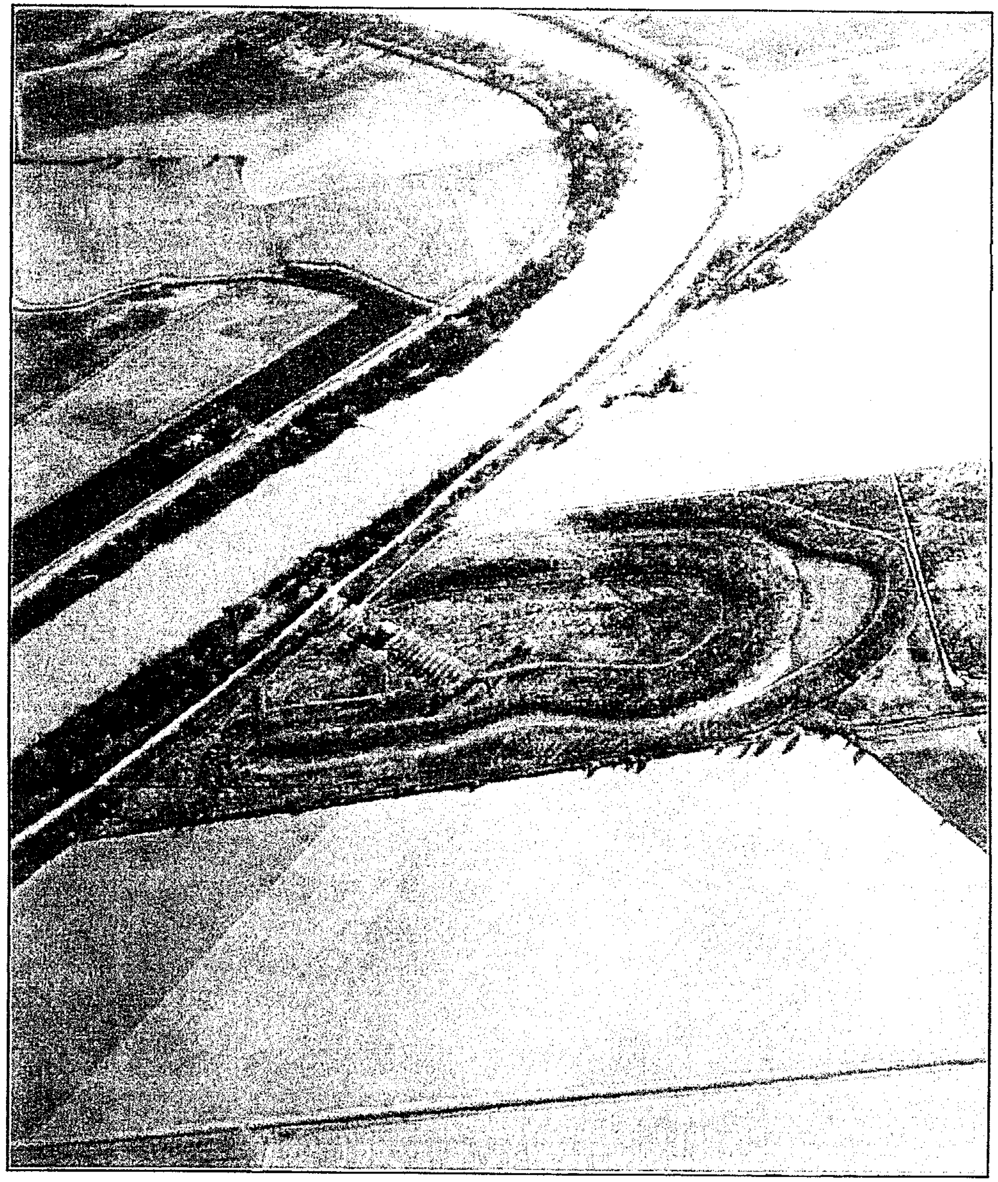

EXHIBIT 7-12: KACHITULI OXBOW ON RIGHT BANK OF THE LEVEED SACRAMENTO RIVER
(PHOTOGRAPH BY DAVID KELLY)

### ☼ SECOND YEAR

At the end of the second monitoring year--1993-- the problem of rodent herbivory and invasion of exotic grasses became a major problem and required corrective action. Management procedures were set out for subsequent years. During the second year, bird usage of the site increased dramatically in terms of species. Fifty-nine species were observed in the second survey (Jones & Stokes Associates, 1993).

### ☼ THIRD YEAR

By 1994, the plant communities had matured and had exceeded the performance anticipated for this stage of development (Jones & Stokes Associates, 1994). Rodent herbivory was controlled, but the invasive exotic grasses and weeds required continued monitoring and managing. The more mature state of the cottonwoods, willows, elderberries, and grasslands provided better habitat values and consequently continued to retain and attract bird populations. The surveys associated with the third year monitoring report show that the bird species had stabilized--56 species were observed in the 1993-1994 survey as opposed to 59 species observed in 1992-1993.

### ☼ FOURTH YEAR

By the fourth year of monitoring--1995--the plant communities seemed to be on track to meet the 5-year performance criteria. Despite a problem with the sycamore trees, the survival and growth rates of the woody vegetation were reported to be satisfactory. Only minor adjustments to the weeding and irrigation programs were recommended (Jones & Stokes Associates, 1995).

The abundance in number of bird species using the oxbow portion of the site fell during this monitoring period; however, this was considered to be a temporary phenomenon, largely attributed to the prolonged wet and cold spring and inundation of the mud flats that had developed around the open water areas. The number of species observed over the entire site fell from 56 to 34. Still, the well-established plant communities and their usage by wildlife convinced the COE that a fifth year of monitoring was not necessary. On January 27, 1997, the COE concurred with the designers and implementers of the Kachituli Oxbow mitigation project that the requirements of the Section 404 permit had been met. The COE called the mitigation "successful and complete." They concluded that the Kachituli Oxbow was in compliance with the terms and conditions of permit 9051 (Exhibit 7-12).

## CONCLUSIONS

The success of the project stems directly from the interest and involvement of regulators and citizen groups and the expertise of the designers. On first analysis, the concept for the Kachituli Oxbow mitigation plan was rather radical--converting a tomato field to riparian habitat. Although in geologic time there may have been an oxbow present on the property, there certainly was no evidence of this geomorphic structure on the preexisting alluvial soils. However, careful analysis of the soils and soil stratigraphy in advance yielded a plan and project that was successful. Specifying the geomorphic form, of course, was only part of the conditions for success. There were two remaining components, the hydrology and plant communities.

Predesign analysis of the site revealed the presence of groundwater, which would be intercepted by the intended geomorphic structure. This knowledge ensured the presence of an adequate sustainable water supply. During the transition and establishment of plant communities, this supply had to be supplemented, as the designers clearly understood. Consequently, an elaborate irrigation system was put in place and used to provide the necessary moisture for plant establishment.

The plant communities and their appropriate landscape positions were well thought out and implemented. This was clearly facilitated by the predesign analysis of similar habitats that still existed along the Sacramento River. The firsthand experience and understanding of these habitats contributed significantly to the success of the Kachituli Oxbow mitigation project. Another contributing factor was the ongoing management and monitoring, which is to say "adaptive management." When weeds and herbivory became a problem, they were overcome by aggressive action, which prevented the mitigation from taking an unwanted course.

On August 16, 1997, the title to the Kachituli Oxbow property was transferred to the California State Lands Commission. This agency will be responsible for the long-term management of the property. The intention is to open the project to public use with an emphasis on education.

## ACKNOWLEDGMENTS

Representatives of the regulatory and resource agencies, design firms, and interested parties participated in the preparation of this case study. Although some were not involved in the early stages of the project's development, they were all well informed on the history, objectives, and technical issues of the project. June de Weese with the FWS in Sacramento, California, spent a great deal of time discussing the project with the authors and providing background information. She coordinated a site visit, which included representatives of the COE, the EPA, and the California State Lands Commission. Also in attendance were the designers and implementers of the project including Miriam Green of Miriam Green Associates, David Kelley of Kelley and Associates Environmental Sciences, Inc., and Ellen Davis of Jones & Stokes Associates, Inc. A number of people have written about the project and their documents were used extensively. Where particular concepts or observations were noted, every attempt was made to properly credit the author.

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# CHAPTER 8

## CONCLUSIONS

These case studies show that restoration can result in viable ecological communities that are similar in structure and function to natural ones. The unique, rare wetland types will remain difficult to re-create until more is known about them and sufficient experience gained from their restoration. For such wetlands, preservation might be the best answer. Meanwhile, there is a great need for wetland restoration in the United States, and sufficient knowledge is now available to successfully restore or re-create a wide variety of wetland types.

As we have discovered in the past few decades, wetlands make our country a better place in which to live. Wetlands provide us with more ducks and geese to travel our migratory flyways, less devastating flooding along our major rivers, and clearer and healthier surface waters for swimming and fishing.

Avoidance and minimization will continue to play a key role in the Section 404/Clean Water Act permitting process. The Transportation Equity Act for the 21st Century (TEA-21) provides greater flexibility for compensatory mitigation of unavoidable wetland impacts. A large-scale increase in wetlands in North America has become a national goal through the Administration's Clean Water Action Plan, and managing wetland impacts on a watershed basis is a key strategy in achieving that goal. Where wetland restorations can be done well, they should be done; where uncertainties remain, we should proceed with caution; and where rare wetland types exist that cannot be duplicated, they should be preserved.

The four restoration projects described in this report were judged to be successful by those most closely involved. Success criteria applied to restoration projects ranged across a wide variety of scientific and non-scientific standards, from species-specific survival rates to general hydrologic conditions. Such criteria, whether defined by the public or the scientist, were important in guiding the restorations toward the desired goals. The goals, objectives, and criteria for restoration should be established in relation to the water regime of the drainage basin and ecosystem in which they lie. In this context, it is possible to address the often neglected wetland benefits of water quality management, flood control, and erosion control, which should be reflected in the success criteria for every restoration project. Even if the specific biological criteria for a mitigation project are not immediately satisfied, the other wetland functions may be exhibited, facilitating biological success at a later date. Wetlands failing to meet specific habitat objectives can still store water, thus preventing downstream flooding, as well as providing adequate detention time for the removal of sediments, nutrients, and other constituents. Although, at times, the short-term goals that defined the success of the mitigation project may not be met, the restoration of topography and hydrology on the set-aside land provides future opportunities for meeting them.

Successful restoration projects will be located appropriately in the landscape. An inappropriately placed wetland may negate the objectives and criteria for its restoration or creation. The land benefits can be realized only if they are perceived and utilized by the people that are affected by them. Wetlands restored in locations remote from public access may benefit wildlife but might not satisfy human recreational, aesthetic, or educational needs.

The landscape position is also important for the establishment of the all-important hydrologic characteristics. Locating restored wetlands too low on the landscape may result in excessive inundation and/or the development of a type of wetland not critically needed. Wetlands positioned too high on the landscape, on the other hand, may not have available a supply of water essential for successful restoration.

The models for successful landscape position and hydrology, as well as for plant communities and other attributes, often exist in natural landscapes near or adjacent to the site. Gaining design parameters from the proven relationships within these landscapes for the development of the desired wetland type has been shown to be a successful strategy.

Successful restoration projects will involve a wide variety of interest groups and institutions. The role of the scientist, particularly in the botanical disciplines, is well established. What is less clearly appreciated is the role that the governmental institutions and the public play. The case studies in this report showed the value of a keen interest on the part of the professional staff guiding the regulatory and mitigation processes, as well as consistent public involvement. Properly focused, the dialogue between various interests is important to the development of successful mitigation projects. Without the legislated regulatory process, this dialogue would not likely take place, and certain interests would be depreciated and ignored. The National Environmental Policy Act of 1969 (NEPA) and Section 404 of the Clean Water Act have become essential elements in this dialogue with its promotion of effective and beneficial restorations of aquatic landscapes.

Successful restoration projects will foster an active, dynamic process that extends from early planning far beyond the completion of construction into management and monitoring. Agreement on mitigation design is only the first step.

One of the most important steps--construction--is frequently downplayed. Construction includes grading, planting, and the placement of hydraulic control structures. As these elements are put in place in various combinations, careful supervision is needed on a continual basis. Mitigation expertise should be applied at every level of construction management and the subsequent site maturation process. Although design drawings and construction specifications are important, a clear understanding of the goals and objectives of restoration and the construction process by the supervising engineer or scientist is essential in accomplishing a successful project and can even compensate for the absence of such documentation.

Monitoring is the next step in the process; without monitoring, effective management cannot take place. Conversely, without management, the monitoring effort is largely wasted. Clearly, both short- and long-term monitoring and management are essential to meeting the goals set for the restoration project.

Successful restoration projects may have led the participants in directions they could never have anticipated. Although most engineers (and even scientists) believe that the application of well-researched principles will lead inevitably to a particular mitigation result, experience does not support this view. Serendipity played a significant role in the case studies and can be used to advantage by creative and flexible practitioners of wetland restoration elsewhere.

Successful restoration projects need continued management. The completion of a restoration project is only the first step; it is the beginning of life for the restored landscape. The survival of that landscape and the gathering of benefits from its involvement in the environment will be sustained only if the landscape continues to prosper; for this, long-term ownership and management is essential.

The four restoration projects described in the preceding chapters provided some insights into the elements that constitute success, leading to the general conclusion that there is no single way to reach that goal. In looking at the planning, the implementation, and the role that people played, officially and unofficially, in their development, certain themes emerge from an examination of the four projects.

The following observations and recommendations are based on the analysis of the case studies in the context of their role in the natural landscape and the importance of compensatory mitigation in Federal wetlands policy today.

## PLANNING AND DESIGN

Ideally, the planning and design process for mitigation projects should begin at the watershed level, based on an analysis of the basin-wide effects of wetland losses and gains. Although flood control and water quality improvement cannot be achieved in a 24,282-hectare (ha) (60,000-acre) watershed by the addition of one or two 2.02-ha (5-acre) wetland mitigation projects, the strategic placement of 100 or 1,000 of those small projects will have a substantial cumulative effect.

Watershed planning for wetland protection and restoration was not commonly practiced when the projects in this report were executed but, to the extent that the broader ecological and hydrological regimes were understood and considered in their development, these projects benefitted. The damaging impacts of the construction projects were analyzed in the context of regional needs: 1) the riparian and elderberry beetle habitat needs mitigated by the Kachituli Oxbow were first defined in terms of watershed and then national deficiencies; 2) the Keys bridges mitigation satisfied the requirements of the broader ecosystem that encompassed the Florida Bay and extended into the Atlantic Ocean; 3) both the Hoosier Creek and Yahara River Marsh projects were sensitive to and considered impacts upstream and downstream from the specific projects.

The consideration of whether the mitigation activities should take place on or off the project site and provide in-kind or out-of-kind restoration varies by individual project. Planners in the case studies made every attempt to place the restorations at the point of impact, with varying success and significance. The Yahara restorations were implemented in the complex of marshes being affected; however, in Hoosier Creek, the Kachituli Oxbow, and the Keys bridges projects, on-site mitigation proved to be either impossible or potentially far less productive than the off-site restorations that were ultimately accomplished. Restoring a riparian habitat adjacent to the intense urban landscape along the Sacramento River made far less sense than creating the Oxbow because the continued disturbance of the former site would have diminished if not destroyed its effectiveness as a restored habitat, and the Kachituli site was able to provide the needed habitat and desired benefits far more efficiently. The Hoosier Creek restoration not only produced the desired compensation for the lost wetlands, but was also able to correct environmental degradation that occurred in the past. Likewise, by going off site in the Florida Keys, the project designers were able to restore and enhance, with a minimum of effort and investment, hundreds of hectares of former wetlands that had been rendered useless by past construction projects. In the latter case, however, the compensatory, off-site restoration of sea grass and mangroves did not reduce the erosional impacts at the bridge locations.

Some wetland functions, such as groundwater recharge, flood control, and water quality management can be provided by a wide variety of wetland landscapes, which render moot the tradeoffs between in-kind or out-of-kind mitigation. Yet wetland mitigation is often tied to a particular plant community or habitat. The replacement of shrub carr by sedge meadow, as was the case at Hoosier Creek, resulted in an out-of-kind mitigation. The end result was still highly desirable and acceptable, although the habitats are quite different. A useful exercise would have been to assess the two communities, their roles, and potential benefits or deficiencies in the broader watershed and ecosystem. In this context, either habitat may have been acceptable. Further, most of the organisms, including the plants, could move between the site of impact and restoration, via Hoosier Creek or some other pathway. The tradeoffs between the proximity of mitigation to impact and the exchange of wetland types within or between watersheds should be carefully considered in the planning and design process. And, given the unpredictability of the mitigation process, consideration of a range of wetland conditions might be better than the highly specific determination of a single landscape type and specific location. The design could involve alternative habitats that are needed in the region and that could develop despite the designer's best intentions.

Mitigation ratio, that is, the mitigation area divided by the affected area, is increasingly a subject of debate. Regulatory agencies argue that the uncertainty of successful restoration (compensatory mitigation) makes it desirable to require larger areas to be restored than were lost, so as to compensate for those mitigation projects that fail. There are indications of a significant failure rate in some areas. In some cases, this ratio includes buffers surrounding the wetland or uplands within a matrix of wetlands to provide complex edge and diversity of habitat. In the case of the Yahara River Marsh, the ratio was 1:1, but this was a very early mitigation project. In the case of the Kachituli Oxbow, the mitigation ratio was as high as 2.5:1 for specific habitat types. In Hoosier Creek, the ratio was 1:1, and in the Florida Keys what started out as 1:1 ended up vastly greater through voluntary efforts of the Florida DOT and unforeseen results.

The planners and designers for each of the case studies established success criteria. These criteria, in every case, focused primarily upon the plants and plant communities. By association, wildlife habitat structure was inferred, but no specific analyses or design parameters were established for this habitat except in the case of the elderberry beetle (which does not have a wetland habitat) at the Kachituli Oxbow. Even at the Florida Keys project where hydrology and water quality issues were important to the planners, the success criteria were limited to numbers of mangroves and hectares of sea grass planted and surviving.

None of the mitigation project designs or evaluations specifically addressed flood storage, water quality, recreation, or aesthetics. In the designs for the Yahara River Marshes, the riparian habitat associated with the Kachituli Oxbow mitigation project, and the inland lagoons revitalized in the Florida Keys, there were no specific plans developed for public access or use of the mitigation sites. Yet aesthetics were no doubt unofficially considered by the designers in selecting the plants and structuring the plant communities.

As with aesthetics, landscape position was a design consideration that was not explicitly addressed yet was incorporated into each project. The existing matrix of marshes in which the Yahara River mitigation project took place defined and fixed the landscape position of each of the individual restoration projects. In the case of Hoosier Creek, the design engineers established an appropriate hydrologic position in the landscape by installing the downstream hydraulic control structure, which was improved by the adjustments made by beaver shortly thereafter. The end result was a properly positioned landscape element. In the Florida Keys, the inland lagoons where tidal reconnections were established replicated the naturally existing lagoons.

One very important design activity that was illustrated in the Kachituli Oxbow project was direct emulation of the landscape. In this case, the designers went into the field and measured the prototype model, which was riparian habitat. They selected existing riparian habitats close to the mitigation site and then developed plant lists, tree species densities, hydrologic settings, and a variety of other parameters. They then used these parameters to design a riparian habitat associated with the sculpted oxbow. In reality, the designers of the other mitigation projects engaged in a similar process but not so specifically. The surrounding marsh along the Yahara River provided the designers of this mitigation project with firsthand observations of the plant communities and landscape positions, as did portions of the upper Hoosier Creek environment. The difficulties in establishing new sea grass meadows along the Florida Keys could have been reduced, it appears in retrospect, if the emphasis had been put on duplicating the basic conditions under which sea grass thrives. The mitigation effort that relied upon planting sea grass sprigs near the bridges was largely unsuccessful; on the other hand, the conditions that were created in the lagoons by reestablishing tidal connections produced the spontaneous development of new sea grass beds.

Hydrology was the major design consideration in all four case studies. Groundwater observations were made at Yahara River, Hoosier Creek, and the Kachituli Oxbow. Ocean tidal flows were a critical design factor in the case of the Keys bridges. Surface water was the dominant force for Hoosier Creek and the Yahara River Marshes, inundating both sites and controlling groundwater elevations. Little or no surface water influences existed at the Kachituli Oxbow, with this system being driven almost entirely by groundwater and local precipitation. The lack of proper understanding of hydrology is one of the major contributing factors to failed wetland mitigation projects; the case studies, however, illustrate the benefits of understanding the hydrologic regime associated with restoration and demonstrate the design considerations that led to successful mitigation.

## IMPLEMENTATION

Implementation of wetland mitigation, in each of the four projects, consists of construction, management, and monitoring.

### --Construction

Construction activities involve clearing, grading, planting, erecting control structures, and most importantly, managing these activities. Grading may take many different forms and be utilized to accomplish a number of objectives. At smaller restoration projects, such as Hoosier Creek, a backhoe is of sufficient capacity to remove unwanted materials and level the restoration site. In other cases, as in the Kachituli Oxbow project, mass grading is done by bulldozers and scrapers. Trucks may be necessary to remove the unwanted material, such as the foundry sand removed from the Yahara River mitigation project. Backhoes may also be used to help place the hydraulic control structures, such as the one used in Hoosier Creek, to raise the water levels upstream of the railroad embankment, and to install the culverts that allowed the tidal flushing in the Florida Keys lagoons. Planting is done in a variety of ways, using a variety of materials. Without the necessary expertise at hand, grades can be missed, control structures inappropriately located, and plantings done incorrectly. Problems with materials or procedures arise at every step. In all the case studies, a number of people participated in construction supervision. Despite careful observation, errors can and do occur. The wrong species of plants were installed in portions of the Yahara River Marsh and had to be replaced later, after detection by the construction managers.

In the four case studies, independent construction managers or supervisors, representing the mitigation interests, were present. These managers were independent of the construction contractors, which gave the observers the degree of independence and freedom necessary to ensure quality work. It also made available the expertise that was necessary to deal with the inevitable design changes which occur in the field. Trained scientists and engineers, such as those working on the Yahara River and Kachituli Oxbow projects, were able to obtain the cooperation of the construction contractor to allow some experimentation with changes during the course of construction. The Florida Keys project, particularly, was implemented in the early days of wetland mitigation, and little experience was available to guide the construction of mitigation. Without fixed rules and long tradition, there was a greater need for advice and guidance provided by experienced field observers.

### –Management

Management and monitoring are an essential part of the mitigation process, and construction should not be considered complete until the construction specifications have been confirmed as met by inspection. Subsequent to completion of construction, monitoring is important to establish that the mitigation site is meeting performance objectives. The extent and appropriateness of the management programs depended on gathering information about the establishment of the appropriate hydrology and the development of the plant communities. Failures in mangrove propagation led to the search for new locations in the Florida Keys; invasion of rodents and exotic plants led to new management decisions in the Kachituli Oxbow; the implementers at Hoosier Creek had to react to beaver activity; and the problems with Yahara River Marsh plantings required last minute changes. Without this kind of monitoring information, the management of these projects would be a wild guessing game likely to lead to the loss of many of the desired and intended attributes of the new landscapes. The monitoring data alerted the managers to the necessity of providing irrigation water, altering grades slightly, and combating predation and weed infestations. Monitoring data improved the survival of seedlings in the riparian habitat of the Kachituli Oxbow and the ultimate development of sedge meadows in the Yahara River Marsh.

**–Monitoring**

The extent of the monitoring phase varied among the case studies. A minimum of 3 years was required for all and, in some cases, as many as 5 years. At the end of the monitoring program for three of the projects, the regulatory agencies were unanimous in their agreement of the success of the new landscape. In the Yahara River Marsh and at Hoosier Creek, however, the implementing agencies continued to monitor the sites. In the fourth, the Florida Keys, the regulatory agencies essentially gave up on the sea grass mitigation, only to be rewarded over 10 years later by evidence of successful restoration of beds as a result of the project. The Keys provided the only example of true long-term monitoring, but it was also the only project where sufficient time had elapsed to allow it. Long-term monitoring, perhaps on a periodic basis, could have considerable value in the assessment of restoration techniques, the evaluation of the sustainability of mitigation wetlands, and the determination of the landscape value to the surrounding community. Synoptic monitoring every 5 years may be sufficient to provide this information.

Despite all the careful planning and design of the mitigation projects, an element of serendipity was important in several of them. The Hoosier Creek mitigation project was intended to produce a shrub carr habitat, but ended by providing a good measure of sedge meadow. Unanticipated by the designers, the remnant sedge meadow began to assert its landscape position and extend into the restored area, displacing the willows that had been consumed by elk and other herbivores. The landscape that resulted from this chance occurrence was as much admired and highly valued as the intended shrub carr could have been. Similarly, the failure of the initial sea grass mitigation along the route of the Florida Keys bridges was more than compensated for in the sea grass meadows that flourished in the lagoons that were flushed for the exclusive purpose of stimulating mangrove restoration. These accidental results added substantially to the overall value of the restoration projects.

## INSTITUTIONAL AND PUBLIC COMMITMENT

Section 404 of the Clean Water Act, the 404 (b)(1) guidelines (40 CFR 230), and NEPA were important in achieving benefits of environmental review and compensatory mitigation. The conditions under which the bridges carrying the Flagler Railway (in Miami, Florida) were first constructed--which must have caused substantial environmental damage--would never be permitted today. Section 404 and NEPA have brought a variety of public and private individuals and institutions into the process that provide both the expertise and the interests that produce environmentally sound development projects. They have established the priority for wetland protection and mitigation and set the forum for public debate.

Even in the early stages of their influence, these pieces of Federal legislation required the various developmental organizations not only to mitigate for wetland losses but also to avoid and minimize substantial environmental damages in the design of the developmental projects themselves. The Yahara River Marsh project, first proposed in the 1960s and finally completed in 1988, was the first wetland mitigation project undertaken by the Washington Department of Transportation (WDOT). During the negotiations with environmental interests, design changes were made that reduced wetland acreage to be destroyed from the original 72 to 31 and finally down to 8.90 ha (22 acres), and actual construction resulted in a loss of only 7.40 ha (18.3 acres). The Florida Keys project was initiated before the U.S. Army Corps of Engineers had established procedures for implementing the Section 404 permitting process. Yet by encouraging all the parties to sit down at the same table to negotiate, substantial accommodation of environmental interests was achieved before the actual permits were applied for, and the replacement of the old bridges with causeways that would have affected the complex hydrology of the region was avoided. In the Kachituli Oxbow project, the applicants reduced the acreage of destruction of elderberry beetle and riparian habitat before construction occurred.

The process, in all the cases, produced vigorous public debate about the pros and cons of the project and the associated mitigation needs. Both in Wisconsin and in California, these debates elucidated the importance of the wetlands or habitats being lost and the specific needs for their restoration. Despite the antagonism between proponents and opponents of the project, in the end they worked together to produce mitigation successes that resulted in a new understanding of the landscape functions to be restored, the quality of restoration necessary, and even the techniques to be employed.

For whatever reasons, a cadre of people began to form in all the case studies, in both the public and private sectors, that had a special interest in the restoration efforts and a commitment to make them work. It was the ability and enthusiasm of these people that led to the ultimate success of each of the mitigation projects. Without the commitment of the field engineer working for the Colorado Department of Transportation, the hydrologic control structure would not have been constructed as exactingly as it was, creating the appropriate hydrology for the sedge meadow that eventually developed. The university scientists and young wetland ecologists working for the WDOT carefully followed and observed the construction process, helping them along the way to make adjustments that were necessary to the success of that project. The Florida Department of Transportation's efforts to find new sites for mangrove plantings produced an unanticipated and spectacular success that was discovered and documented years later, as the result of one participant's continuing interest in the project. At the Kachituli Oxbow, the construction managers were consultants hired by the project developer. The consulting staff had a long involvement in the project and the mitigation design. They were skilled scientists, committed to environmental protection and restoration, and they were supported by committed members of local environmental groups and representatives of the regulatory agencies. Combined, these human resources provided an essential ingredient to the success of the wetland creation. The four case studies were successful partly because they modeled the natural prototypes very closely, but most importantly because they involved dedicated and knowledgeable individuals who ensured that during the planning, design, implementation, and management phases important ecological relationships were created and maintained.

## LONG TERM SUCCESS

The long-term success of the case studies and all the other mitigation projects implemented across the country will depend upon the future management of these restored landscapes. Each of them is owned and managed by public entities which, in some cases, will provide public access where appropriate and even modify them to better meet future needs of the watershed and the region. Each of the newly created landscapes was considered a success, yet what is more important is that the land has been set aside and protected from development. The benefits of wetland functions can be garnered from these new landscapes to whatever extent is considered valuable. Whether these functions are optimized or not is less important than the preservation of these landscapes for these future opportunities.

Many of the Nation's wetlands have been, and more will continue to be, lost to the economic necessities of contemporary life. Each of the four projects mitigated wetlands which were lost to important and substantial development projects. The two highway projects were reasonable and responsible solutions to problems created by population pressure; they were the effect rather than the cause of the inevitable population increases experienced everywhere in the country. The Florida Keys project, intended to maintain a safer status quo, was conservative in design. Rather than widen the bridges from two to four lanes, which would certainly have increased traffic into the fragile Keys environment, the project was restricted to a stronger, more substantial replication of the original two-lane bridges. The Colorado project, likewise, produced a wider, safer roadbed without increasing the capacity of the highway; and the beltway serving Madison, Wisconsin, was way overdue in servicing its auto-dependent clients. In Yolo County, California, economic development was a reasonable goal that would have been served well by the imaginative planned development. Economic development cannot be stopped nor should it be. It can proceed in orderly and responsible fashion, as it did in the four case histories, providing a mechanism for solid wetland gains that can and often do extend beyond a simple compensation for wetland losses.